USABILITY EVALUATION OF A VENDOR'S EMERGENCY DEPARTMENT COMPUTERIZED PROVIDER ORDER ENTRY APPLICATION AT THE UNIVERSITY OF UTAH HOSPITAL

by

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A thesis submitted to the faculty of
The University of Utah
in partial fulfillment of the requirements for the degree of

Master of Science

Department of Biomedical Informatics

University of Utah

December 2012

The University of Utah Graduate School

STATEMENT OF THESIS APPROVAL

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ABSTRACT

66% of all IT projects either fail outright or take much longer to install than expected because of their complexity. —The Economist, October 2004

Electronic Health Record (EHR) adoption rates have been low in the United States. A key reason for this low adoption rate is poor EHR usability. Currently no standards exist for design, testing and monitoring the usability of EHRs. Therefore, we conducted a usability evaluation of a vendor's product in the Emergency Department at the University of Utah. In the first objective of this study, we evaluated a newly implemented computerized provider order entry application. Four usability experts used the Zhang et al 14 heuristics and 23 predefined tasks to perform the evaluation. The experts found 48 usability problems categorized into 51 heuristic violations. There were 4 cosmetic, 120 minor, 64 major, and 4 catastrophic problems identified. The interrater reliability was 0.81 using Fleis' Kappa, showing a high level of consistency in ratings across evaluators.

For the second objective, we used an electronic version of Questionnaire of User Interaction Satisfaction (QUIS 7.0) to evaluate physician satisfaction with the CPOE application in the ED. The physician response rate was 50% (25/50). The total survey mean was 4.87, lower than the "a priori" definition for acceptable satisfaction score of 5.0 (of a possible 9). The lowest scale scores were for overall user reaction and learning

and the highest were for screen, terminology and system capabilities. Further analyses were completed to determine any differences for satisfaction scores between physician trainees and attending. A multifactor ANOVA was performed to examine the combined effect of the different experience levels and sections of the QUIS. The results were significant at -1.43 ($p < 0.05$) for screen and terminology and system capabilities.

In this setting, the ED CPOE application had a high level of usability issues and low mean satisfaction scores among physician end-users. The responsibility for improved usability lies with both vendors developing the product and facilities implementing the product and both should be educated on usability principles. The combination of a user-based and expert-based inspection method yielded congruent findings and was an accurate and efficient means of evaluation.

This thesis is dedicated to my mother Jahan Ara Zafar, younger sister Kanwal Zafar and especially my father Zafar Iqbal who has always been there for me as a support, as a guide, as a friend and as a father.

If we knew what it was we were doing, it would not be called research, would it?

—Albert Einstein

TABLE OF CONTENTS

LIST OF FIGURES

Figure

LIST OF TABLES

Table

ACKNOWLEDGEMENTS

I would like to take the opportunity to acknowledge my chair and mentor, Nancy Staggers, Ph.D., Department of Nursing Informatics and Department of Biomedical Informatics, University of Utah. She is very knowledgeable, inspiring and has been very kind and supportive in helping me achieve my goals and the completion of this degree. I am fortunate to have a chair like she is. I thank my committee members, John Hurdle, M.D., Ph.D., and Bruce Bray, M.D., who have supported and mentored me throughout this entire fellowship not just my research. I consider myself fortunate to have committee member like them; it was a pleasure and a learning experience to work with all of them.

I would like to acknowledge the chair, Joyce A. Mitchell, Ph.D., for providing us such an excellent environment in which we can learn and work. I would also like to mention some faculty I had a chance to work with such as Catherine Staes, Ph.D., Scott Evans, Ph.D., Jennifer Garvin, Ph.D., and Stephane Meyestre, M.D., Ph.D. They have been very kind and helpful.

I would also like to acknowledge the Department of Information Technology and Department of Emergency Services, University Hospital of Utah, their entire team, especially Eric Barton, M.D.

I thank my classmates, Shan He, Sang Hoon, David Taylor, Laritza Taft, Sharanya Ragunath, Yuling Jiang, Anthony Wong, Martin Cryer, Bryan Gibson, etc. Everybody made it a memorable experience for me. I will never be able to forget this lovable, pleasant, friendly learning experience.

CHAPTER 1

INTRODUCTION

Inadequate use of usability engineering methods in software development projects have been estimated to cost the US economy about $30 billion per year in lost productivity. —Jakob Nielsen (1)

Electronic Health Record (EHR) adoption has been very slow for the past 20 years in United States; multiple reasons exist including costs, resistance to change, fear or avoidance of technology, and ingrained patterns of behavior. Recently usability has been acknowledged as a key factor for adoption and appropriate utilization of EHR, and it is an important issue to be addressed (2, 3). Billions of dollars are being spent on EHR implementation, adoption and meaningful use under the HITECH act (4). Although usability has been highly associated with end-user adoption of the EHR system, it has not been given much attention. A recent study identified information about current EHR vendors usability processes and practices during different phases of Product development and deployment as a research gap (3). Studies have been published on the impact of CPOE systems on the workflow and medication errors (5, 6) but very little work done to study the impact of usability on the effectiveness of a system, workflow, end-user satisfaction and patient safety. The genesis of this study was to evaluate the effect of an application that did not benefit from a usability evaluation, on the efficiency and effectiveness, and its impact on clinical workflow, patient safety and end-user satisfaction. This objective was successfully achieved by the following two evaluations:

(1) Heuristic evaluation of a newly implemented Emergency Department Computerized Provider order entry application by using the Zhang et al. Heuristics (7) on which a formal usability evaluation was not performed;

(2) Evaluation of the user satisfaction of the same application by using Questionnaire of user interaction satisfaction (QUIS 7.0) (8)

CHAPTER 2

BACKGROUND

Usability techniques can streamline data entry and allow for a 10-fold decrease in the average number of reported user problems. (9)

Better-designed systems can allow for correct data entry, display, and interpretation, and can contribute to sound clinical decision-making, potentially preventing errors (10). “Human Factors” is a discipline that is concerned with developing such systems. Human Factors is the study of the interaction between people, machines and their work environment (11). One of the areas within Human Factors is Human Computer Interaction (HCI), HCI is the study of how people design, implement and use interactive computer systems and how these systems affect individuals, organizations and society (12). One important aspect of HCI is the usability testing of such systems. Usability is a subset of Human Computer Interaction and addresses specific issues of human performance during computer interactions within a particular context (13). Employing usability techniques means designing or purchasing systems that require a minimum of learning, ease of using application, ease of remembering interaction methods, user-satisfaction with the system, efficiency of use, error free interactions and seamless fit of an information system to the task at hand (14). Usability testing can help identify unanticipated design problems.

Invariably, the essence of usability testing is to make appropriate modifications to the technology that is the object of study. Usability of a novel technology is determined by the effectiveness, efficiency, and satisfaction with which users achieve specific sets of tasks in a particular environment. Effectiveness refers to how accurately and completely users of a system can achieve specified goals; efficiency refers to the resources utilized in relation to the accuracy and completeness of goals achieved, and user satisfaction refers to the ease and acceptability of the system to its users (15-17).

There are various inspection methods to evaluate the usability of a system design. They can be broadly categorized into expert-based inspection methods and user based inspection methods. Inspection methods are useful because you do not need the actual users to perform the evaluation, which can be costly and difficult, it is cost effective and the best results are achieved by combining a user-based and an expert-based method (18). The most common expert based inspection methods are guideline review, heuristic evaluation, consistency inspection, usability inspection and cognitive walkthroughs. User-based testing methods can include user performance measurements, log-file and keystroke analyses, cognitive workload assessments, satisfaction questionnaires, interviews and participatory evaluation (19-23). User-based testing is more accurate as it is performed by the users itself; however, due to resource limitations and time limitations it is not always possible to get users to perform the evaluation. This is one of the biggest limitations of user based testing. As far as the expert based testing is concerned: In Guideline review methods user involvement, user feedback from early prototypes and iterative development—guidelines can play a role in improving the quality of the iterative steps, leading to an improvement in quality and reduction (but not elimination) of the

number of iterations involved in the design-evaluate-redesign cycle of HCI development (24). There are a number of concerns about the nature of guidelines that can inhibit the impact of guidelines on the design of user interfaces (25, 26) apart from not adequately addressing concerns facing software developers, such as which guidelines should be used under what circumstances (27), studies have shown that interface guidelines suffer from being too abstract to directly apply (27-29).

Consistency inspection methods have designers representing multiple projects inspect an interface to see whether it does things in the same way as their own designs (30). Lack of consistency can be a major problem for users. Consistency is spreading across applications so that there are common mental models for users to understand how different interfaces will work. This kind of inspection looks for areas of inconsistent operation within a system and between the evaluated system and other existing systems (31).

Cognitive walkthrough is a usability inspection method that evaluates the design of a user interface for its ease of exploratory learning, based on a cognitive model of learning and use (32). It does not provide guidelines about what makes an action clearly available to a user and it is not known what types of actions are considered by a broad range of users. The two main limitations of cognitive walkthrough are the repetitiveness of filling out the forms and the limited range of problems the process found (33-35).

John and Packer found that the method is learnable and usable for novices (36). The process of using the four cognitive walkthrough steps could effectively demonstrate errors that users can make while using a safety-critical interface (37). However, the

choice of task scenario can be difficult; if the scenario is not adequately described, the evaluation is not as effective (38).

Among the usability inspection methods, heuristic evaluation is the most common and most popular (22, 23). In a heuristic evaluation, a small set of evaluators inspects a system using a given list of tasks and evaluates its interface against a list of recognized usability principles—the heuristics.

Heuristic evaluation is an efficient usability evaluation method with a high benefit–cost ratio (39, 40). It is particularly of value in circumstances where time and resources are limited, since skilled experts can yield high quality results in a limited amount of time without the need to involve end-users in the evaluation (41).

Computerized Provider Order Entry (CPOE)

Computerized provider order entry (CPOE) refers to any system in which clinicians directly enter medication orders into a computer system, which then transmits the order directly to the pharmacy. These systems have become increasingly common in the inpatient setting as a strategy to reduce medication errors. A CPOE system, at a minimum, ensures standardized, legible, and complete orders and thus has the potential to greatly reduce errors at the ordering and transcribing stages.

CPOE systems are generally paired with some type of Clinical Decision Support System (CDSS). A typical CDSS suggests default values for drug doses, routes of administration, or frequency and may offer more sophisticated drug safety features such as checking for drug allergies or drug–drug or even drug–laboratory (e.g., warning a clinician before ordering a nephrotoxic medication in a patient with elevated creatinine) interactions. At the highest level of sophistication, CDSS prevents errors not only of

commission (e.g., ordering a drug in excessive doses or in the setting of a serious allergy), but also of omission. (For example, an alert may appear such as, "You have ordered vancomycin; would you like to order serum vancomycin level after the third dose?" or, even more sophisticated: "The admitting diagnosis is hip fracture; would you like to order enoxaparin for DVT prophylaxis?") (42, 43).

A Computerized Provider Order Entry application (CPOE) provides benefit but its configuration can have a great impact on the clinician adoption. A poorly designed CPOE system can cause usability problems, user dissatisfaction and disruption in the clinical workflow (44). Introduction of CPOE offers new functionality, but often-poor user-friendliness and usability of CPOE interfaces impose heavy cognitive demands on users (45-47). This can lead to users' frustration, reluctance to use the system, ordering errors, administration errors due to physician-nurse miscommunications (48), suggesting a threat instead of an enhancement of patient safety. To prevent this situation, a user-centered design process should be followed from the early phase of the CPOE design Process (44). User Centered design is a broad term to describe design process in which end-users influence how a design takes shape (49).

CPOE at the University of Utah

The emergency department of University Hospital of Utah implemented a new CPOE application to improve the workflow but its usability had not been evaluated. Therefore, the main objective of this evaluation was to evaluate the efficiency and effectiveness of this application and assess the impact of the interface on practitioner user satisfaction, clinical workflow and directly patient safety. The specific goals of this study were to perform:

(1) A usability evaluation of the fielded CPOE application using the heuristic of Zhang et al. (7) and expert evaluators;

(2) An evaluation of end-user satisfaction of the CPOE application using Questionnaire of User Interaction Satisfaction (QUIS 7.0) (8)

For this study we used one expert-based inspection method, Heuristic Evaluation, and one user-based inspection method, a Satisfaction Questionnaire, to provide a more comprehensive evaluation of the user interface.

CHAPTER 3

USABILITY EVALUATION OF A VENDOR'S ED CPOE AT THE UNIVERSITY HOSPITAL OF UTAH

Abstract

A key reason for low Electronic Health Record (EHR) adoption rate is poor usability. We conducted a usability evaluation using the 14 heuristic of Zhang et al. for a newly implemented CPOE application in the Emergency Department (ED). The experts found 48 usability problems categorized into 51 heuristic violations. There were 4 cosmetic, 120 minor, 64 major, and 4 catastrophic problems identified. The inter-rater reliability was 0.81 using Fleis' Kappa.

For the second objective an electronic version of Questionnaire of User Interaction Satisfaction (QUIS 7.0) was used to evaluate physician satisfaction for CPOE, the results revealed low user satisfaction.

Low user satisfaction and high number of usability problems were identified. Both the vendor and facility are responsible for low usability and should be educated on usability principles. The combination of user-based and expert-based inspection methods yielded congruent findings and was an accurate and efficient means of evaluation.

Introduction

The American Recovery and Reinvestment Act (ARRA) of 2009 made available billions of dollars for health care providers to adopt and "meaningfully use" certified

electronic health records (EHRs) (50). One of the key factors driving the adoption and appropriate utilization of EHR systems is their usability (51). Yet, no standards exist for designing, testing and monitoring the usability of EHR products. A recent study reported a gap (52) in the current EHR vendor usability processes and practices during the different phases of product development and deployment. The report recommended testing and evaluating usability throughout the product life cycle including post-deployment to ensure patient safety (52). This study is an initial step towards filling this gap (52). In it, we performed a usability evaluation on an Emergency Department Computerized Provider Order Entry (ED CPOE) application fielded at the University of Utah Hospital.

Background

A National Research Council (NRC) report asserted that today's clinical systems provide poor cognitive support for tasks and clinician workflow (53). Usability has a strong, often direct relationship with clinical productivity, error rate, and user fatigue and user satisfaction–critical factors for EMR adoption (51). The usability of EHR systems, while recognized as critical for successful adoption and meaningful use, has not historically received the same level of attention as software features, functions, and technical requirements (e.g., interoperability specifications) (51). Very little systematic evidence has been gathered on the usability of EHRs in practice and the implications of design on cognitive task flow, continuity of care, and efficiency of workflows (50).

Various methodologies are employed in usability engineering to elicit users' points of view, such as interviews, observations, surveys, scenarios and heuristics evaluation (54). Heuristics are rules of thumb that a good user interface should follow.

Heuristics evaluation is a type of usability inspection method, referring to a class of techniques in which evaluators, usually experts, examine an interface for usability issues (7). Inspection methods are considered an informal usability evaluation method; because they rely on heuristics and the experience and knowledge of the evaluators. Previous work has shown the successful use of this methodology on evaluating a CPOE module (55).

CPOE has garnered a lot of attention in terms of time and money in the healthcare arena. Most of these CPOE systems are not designed to address usability issues, current CPOE systems are hard to use, hard to learn and they generate user frustrations and abandonment (55).

Problems with the usability of currently available CPOE systems are a significant cause of poor user acceptance, because they significantly disrupt the workflow of the users (56) and mitigate unintended adverse effects on the clinical workflow (57). Clinicians can lose productivity during the training time (58); lack of usability can increase the time and cost of training and can make the implementation process more complex (51). The University Hospital in Utah implemented a new emergency department (ED) computerized provider order entry (CPOE) module recently to improve the workflow and tasks performed in the emergency department. A usability assessment on this new application is needed to assure that it facilitates the processes in the ED. Hence the objectives of this descriptive, exploratory study were:

Objective 1: Perform a formal usability assessment by using the 14 heuristic of Zhang et al. (7) on a fielded CPOE application in (setting),

Objective 2: Describe physician's user interaction satisfaction with the ED CPOE application at the University Hospital.

Objective 1: Usability Evaluation of a Vendor's ED CPOE

Methods

IRB process. The University of Utah IRB approved the study.

Setting. The evaluation was completed by remotely accessing the ED application in the Production environment. The application is a Computerized Provider Order Entry (CPOE) application from one of the major EHR vendors and was implemented in the Emergency Department of the University Hospital of Utah in November 2009.

Participants. Four usability experts completed the usability evaluation. The evaluation was completed in two months from January-March 2010. These experts were all informaticists trained in usability evaluation by a human system interaction expert. The informatics experts had diverse clinical backgrounds in medicine, public health and physical therapy.

Heuristics evaluation techniques. Heuristic Evaluation as discussed earlier is one of the expert usability inspection methods. It refers to the class of techniques in which the evaluators examine an interface for usability issues. During a heuristic evaluation, experts walk through the interface using typical user tasks and identify elements that violate usability heuristics (7). In this study we used the 14 heuristics of Zhang et al. (Table 1) and evaluated the ED module against these heuristics by using the given task (Table 2). A severity scale score from 0-4 (Table 3) was assigned consistent with the metrics in the Zhang et al. study.

List of tasks. The author developed a list of 23 typical ordering tasks performed in the Emergency department varying from low to high difficulty level. The chief of the Emergency Department validated the tasks.

An example of the task performed is ordering a laboratory test (any). For this task, the evaluator first found a test patient, found the screen to place an order, then would look up the specific laboratory order.

Another example would be to order a medication - Ativan™. In this situation the evaluator again first found a test patient, then navigated to the order screen, and selected Ativan™ to place the order.

Procedure

The four evaluators used the 23 tasks described above to independently evaluate the ED CPOE interface in the site's production system using 14 heuristics of Zhang et al. A severity rating was assigned to each heuristic violated. The evaluator selected a task and went through the multiple steps of performing that task. Any problems or violations found in this process were listed, categorized into one of the 14 heuristics of Zhang et al. and a severity score was given.

The results of the evaluation were compared across experts. Meeting the evaluators independently and discussing their rationale behind assigning the heuristic and rating resolved any discrepancies. A master list of heuristic (Appendix B) violations was developed after all the discrepancies were resolved. We calculated an interrater reliability by using Fleis' Kappa for all four evaluators.

Results

The results are divided into two categories: 1) heuristics violations; 2) overall severity ratings.

Heuristics violations. We found 51 heuristics violations and 48 usability problems. Samples of issues are listed in Table 4. Match (15/51) and Language (11/51) were the two most commonly violated heuristics and accounted for 50% of the violations (Figure 1). Feedback (3/51) was a constant problem though was not listed under each problem. An example of Match violation is the refresh icon; in order to find the status of the order placed the provider needs to click the "refresh" icon else the order status will display processing. Not only that, but the refresh icon is difficult to locate. It is labeled "as of" instead of a more intuitive term like "refresh" (Figure 2). This particular usability problem is also a violation for the feedback heuristic, since there is no feedback on whether the order has been added or not.

An example of a Language violation is when a provider types, "chest x-ray" or "x-ray" in the search box to place an order for chest x-ray; however, nothing appears. Only when one types "XR," a nonintuitive term, does the application pull up the orders for x-rays. Similar language violations were found with the tasks related to ordering an alcohol or ETOH level, CT scan, O2 Saturation. There was no mapping of similar terms and hence the output of the search result yielded nothing unless the specific term was typed.

Overall severity ratings. There were 4 catastrophic, 64 major, 120 minor and 4 cosmetic problems found across the evaluators (Figure 3 and Table 5). The breakdown of the ratings assigned by each evaluator is also shown (Table 6).

Each evaluator rated the “help and documentation” issue as catastrophic. For example, when “allergy” or “order an allergy” was typed in the help box, no data were displayed. The application would pull information only from the index; one would have to browse through the list to find what they were looking for. There is a good chance that it would not be in the list of help thongs provided.

Examples of major problem are (1) not being able to sign an individual order without completing the details for all other orders, (2) duplicate orders (the evaluators were able to create the same order. An example would be a Laboratory order for CBC (complete blood count) twice at the same time), and (3) taking a full seven clicks to place an order for IV fluids.

A few of the minor problem includes (1) no feedback on the completion of a task, (2) no way to back up to the previous screen, (3) when placing an order for ABG there were multiple orders/options without any explanation provided, (4) color coding for critical values; the color green was used for highlighting critical values (same color for both high and low values). One task had no usability problems; creating a favorite folder. It was an easy to perform task without any complications.

The evaluators identified several positive usability features. For example (1) when placing an order for restraints the evaluator found the link to the restraint policy, (2) creating a favorite folder was a very easy task to perform although there was no feedback provided once the folder was created regarding the completion of task; and (3) another positive finding was a link found by a few laboratory orders to the contracted laboratory home page.

Objective 2: ED Physician's User Interaction Satisfaction Survey

Method

Setting. The emergency department implemented a new CPOE application, in November 2009. An EHR application was in place by the same vendor in the inpatient setting. However, the ambulatory centers with the exception of ED were using another major vendor's application. The CPOE application is from a major, global vendor of EHR products and is available across the inpatient setting. The staff physicians were not a part of tailoring the application although physician leaders were involved in developing order sets/care sets for the Utah build. The ED physicians were trained on the application for three months before the go live date. The survey was emailed to the physician five months after the go live date which gives them enough time to get acquainted to the application. The ED physicians at the University hospital completed the survey at the emergency department; the survey was kept open for their access for two months.

Sample. The total number of ED providers using the ED CPOE application was 59, including, physician attending (21), fellows (5), mid level providers (10), residents (15) and interns (9) (Table 7). We concentrated solely on physician usage and for the same reason excluded mid level providers, leaving a total 50 possible. The demographics of the response sample are also shown in Table 7. The interesting finding was that though the attending had more years of experience as compared to residents and interns, the average number of months/years worked on ED CPOE was found to be higher in interns/residents. Also, we found that 68% of all physicians worked more than 8 hours/week on the ED CPOE application, 32% had used just 1 system, only 12% had used more than 3, and the remaining 12% had used more than 4.

IRB. As recommended by the institutional IRB, consent to participate in the study was implied if the providers completed the survey. An email included a cover letter describing the study purposes and privacy protections for responses.

Instrumentation. We developed an electronic version of the Questionnaire for User Interaction Survey (QUIS 7.0) (8) using Survey Monkey. QUIS is a tool developed by a multidisciplinary team of researchers in the Human-Computer Interaction Lab (HCIL) in 1988 at the University of Maryland at College Park. The tool measures overall system interaction satisfaction along six scales (terrible to wonderful, frustrating to satisfying, dull to stimulating, difficult to easy, inadequate power to adequate power and rigid to easy) and hierarchically organized measures of 11 specific interface factors (screen factors, terminology and system feedback, learning factors, system capabilities and technical manuals) on a 9-point Likert scale. QUIS has acceptable reliability and validity in measuring user satisfaction with variety of computer interfaces. Cronbach's alpha was 0.95 for a previous psychometric assessment of reliability, construct validity was determined by correlating item scores with the six concurrent general satisfaction questions, yielding an adequate correlation (59).

At the end of the questionnaire the physicians were asked to give comments about the ED CPOE interface. Questions were: (1) What do you like the best about the interface? (2) Are there any issues you encountered with the interface and (3) What are the top three things you would like to change about the system? The questionnaire took about 5 minutes to complete.

We defined a rating of 5 on each scale as a priori score for acceptable satisfaction. A priori score is set point determined by the Principal investigator before the study began. For the purpose of this study, we excluded some of the subscales not relevant to the ED CPOE module. The sections were as follows: (1) On-line tutorial, (2) Multimedia, (3) Teleconferencing and (4) Software Installation.

Procedure

We collaborated with the chief of the ED to conduct the study. An electronic survey was emailed to the entire Emergency Department provider working at the Emergency Department of University Hospital of Utah. The survey was emailed by the ED chief to 100% of the ED Physicians. The survey was emailed three times over a two-month period. To maximize the response rate, a personal request was also made to complete the survey during one of the ED staff meetings.

Data analysis. We used descriptive statistics to describe the sample and survey results. For further analyses, we divided the responses into two groups by experience. One group was the "Trainee" group, which included the responses from the intern, residents and fellows. The second group was the "attending" group, which included responses from all the attending physicians. We performed a multiple factor analysis of variance by experience level against each section using the R statistical package. Based on the results we also performed detailed analyses by using Tukey's test.

Results

The response rate for the survey was 25. The results of the survey are divided into three sections: (1) survey results (2) multiple factor analysis of variance (ANOVA) by experience level and individual section of the survey, and (3) open ended comments analysis by the end- users.

Survey results. The overall results of the analysis are shown in (Tables 8). The average rating for the entire QUIS survey was 4.86 and the standard deviation for the entire survey was 1.74. We analyzed each section in detail: the section "Screen" scored the highest mean from the users and the section "terminology and system Information" scored the second highest mean higher. The Section "learning" scored the lowest (Figure 5). In the section "Overall user reaction" (Figure 6) the question on the "rigidity to flexibility" of the system had the lowest mean of 3.6. The section "Screen" (Figure 7) had a mean score above the a priori acceptable satisfaction score, but some questions in this section were below the cut score, e.g., on the screen layout "confusing to clear" scored a lower mean of 4.9; on the other hand the question on "difficult to read-easy to read" scored a mean of 6.24. For the section "Terminology and system capabilities" (Figure 8) the overall mean for the section was higher than the acceptable rating of 5, the questions on "error message, phrasing of error message, error message clarify problem, computer keeps informed, error message helpful" and "instruction on correcting error" were lower than the mean. In the section "System capabilities" (Figure 9) the questions on "correcting your mistake" and "undo operation" obtained a very low mean of 3.74 and 3.91. The question on "ease of operation depends on level of experience" had a very high mean of 5.90. The section mean was 4.83, lower than the acceptable rating. The section

"Learning" (Figure 10) had the lowest mean among all the section and the question that had the lowest mean for this section was "number of steps per task" which was 3.6. Lastly, in the section "Technical manual and help" (Figure 11) the overall mean was lower than the acceptable rating and the questions that scored the lowest mean in this section were "content of help" was found to be confusing and "amount of help" was found to be inadequate.

We also separated respondents into two groups by experience level to compare responses between the groups, the trainees (interns, residents and fellows) (Table 9) from Attending (Table 10). We found the means for trainees (Figure 12) higher than the acceptable rating for the sections "Screen," "terminology and system information" and "system capabilities," whereas for attending (Figure 12) the means were higher for sections "overall user reaction" and "Screen." The means for the remaining section were lower than the acceptable rating.

Multiple analysis of variance (ANOVA). The ANOVA results are in Table 11. The p-value for each section (fx) was < 0.001 at 0.05 level of significance, the p-value for experience level (fz) was 0.052 at 0.05 level of significance.

Thus, the p-value combined effect of experience levels on each section was not statistically significant, indicating that there was no major difference on the ratings by experience level on each section. However, when an interaction effect for experience level and QUIS sections was conducted, the effect p-value was significant. The p-value for the interaction (fx: fz) was < 0.001 at 0.05 level of significance (Table 11). This indicates that when looked at individual effect of the experience level (trainee and attending) on each screen it had a significant effect on the ratings. To further analyze the

reason of this p-value, we performed a Tukey HSD (multiple comparison of mean) at 95% confidence level (Table 12).

We further performed a Tukey HSD which is a multiple comparision of means and found that the Sections: "overall user reaction" and "Terminology and System Information" when compared with two groups (Trainee and attending) were significant and the remaining sections were not significant. The ratings given in the above two mentioned sections were significantly different by the two groups (Table 11 and 12).

Open ended comments analysis. We analyzed and summarized the comments by the end users in themes under their respective questions. The themes are based on the experience level (Trainee and the attending). The actual comments are also included (Appendix B).

1) What did you like the best about the system?
    - There were 12 responses (interns=1, Residents=4, Fellows=1, Attending=6) to this question and 13 providers skipped this question.
    - Trainee: Most of the trainees liked predefined order sets and care sets. They do not have to write orders.
    - Attending: The attending found the system as convenient as compared to paper chart. Most of them found it to be effective for routine tasks and not very effective for specialized tasks.

2) What were some of the issues you encountered while using the application?
    - 11 responses (Intern=1, resident=3, fellow=1, Attending=6) for this question and 14 providers skipped this question.
    - Trainee: Duplicate ordering, Difficulty in ordering labs especially unique orders, Radiology and Lab orders are very complicated. The system is slow and one wrong click makes it even slower.
    - Attending: A lot of physicians mentioned duplication of orders between the nurses and the physician, Difficulty in ordering Lab tests due to no interface between the CPOE and Lab, Drug Interaction system was found to be very invasive.
3) What are the top three things you would like to change in the ED CPOE application?
    - There were 13 responses (Intern=2, resident=3, fellow=1, Attending=7) and 12 providers skipped this question.
    - Trainee: More pre-checked care sets, lab and blood ordering is too complicated, specialty lab orders are too complicated, change the entire system.
    - Attending: Duplicate Orders, being able to modify or cancel orders, A new Screen format, More and revised care sets, more specific choices for lab test and radiology.

Discussion

"The primary purpose for new information technology must always be recognized as improvement of patient care" (60). Regulatory bodies are creating multiple initiatives to promote EHR adoption and meaningful use. It would be a disappointment if all these efforts were wasted due to of a critical factor for end-user adoption/User satisfaction (61). Studies have been published internationally on similar systems having usability issues that lead to excessive time loss; increase cost, loss of productivity and patient safety (6).

The results of this study are an excellent example of a system for which end-user feedback was not considered in the early design phase and a usability evaluation was not performed at any stage of development. The results revealed a high number (51 heuristics) of heuristics violations for the ED CPOE interface installed at this site. Such a high number of violations indicate that the application violated all the three goals of usability assessment: effectiveness, efficiency and user-satisfaction. Especially in a setting like emergency department, it could lead to an increase in error-rates, user frustration, fatigue, and lack of user satisfaction, which in turn can lead to low clinical productivity and low quality of care provided to the patient. The problems that were identified in this study can have serious consequences not only on the workflow but also to the facility and patient safety, for example, duplicate orders, no feedback if the order was placed, no online help etc. The criticality of the problems identified through this method is an indication that even a simple method like heuristic evaluation could limit some serious flaws in the system design.

The problems identified from this study were a combination of vendor code and facility customization of the application. An example of the issues related to the vendor's hard coding is the "Refresh" icon discussed earlier. An example of the facility customization is the color-coding of the lab values. This leads us to another important realization that not only the vendor should apply the usability principles but the facilities should also be educated on them.

In general, heuristics evaluation was found to be a cost effective and efficient method to not only discover usability problems and major flaws in the system design but also points out some potential functional issues in the application as well. Functional issues are activities that a system must perform to achieve its desired output.

The response rate of the survey was 50%, which was lower than expected. Some of the reasons for the low response rate might be: (1) emailing rather performing an in person survey, (2) no available incentives (gift cards etc), and (3) time pressures in the ED setting. Even a personal request from the PI and Chief of the ED did not increase the response rate. We concluded that simply emailing the survey was not a very effective way to get responses. The survey responses certainly could be improved by using some kind of incentives to the physician like conducting the survey during lunch hour and providing lunch, snacks, etc. Also gift cards or movie tickets can be used as an incentive. Performing an in person survey was not a good idea in our study since the target population was ED physicians and it is very difficult to gather the ED physicians together in one place.

The survey was done 4 to 6 months postimplementation of CPOE in the ED; however, the provider training on the application was already in process four months

before the go-live date and so the results of the study are not likely due to adjustment issues on the part of the provider. Even though a longer time period of 8 to 10 months might be needed for all to get accustomed to the application, the findings of our study are purely issues encountered by the physician while using the application. Based on our results, overall user satisfaction was lower than the a priori definition for an acceptable rating (Figure 12). When examining the findings by experience level, the attending liked the system better than the trainees on the overall user reaction section, both the groups rated the screen layout higher than the acceptable rating, and in the remaining sections the trainees gave slightly higher ratings than the attending. The reason could be that the trainees have used less system than the attending and did not have much to compare with. As far as "learning" the system is concerned, the trainees have given higher rating than the attending. The reason can be as the age difference between the attending and trainees. The trainees were much younger in age as compared to the attending and the younger generation has grown up with the technology, hence, are more computers friendly. Another reason can be less experience with working on multiple systems.

Overall users seemed to be satisfied with the sections; "Screen, Terminology and System Information" and were least satisfied with the sections; "Learning, Technical Manual/help". Also sections "System capability" and "Overall user reaction" were found to be lower than the acceptable rating.

There was congruence in usability issues between the expert evaluation and user interaction satisfaction findings. For example, "Help and documentation" heuristic violation was considered as one of the catastrophic problems in the system while performing the usability evaluation and similarly on the survey the section "technical

manual and help" had a mean lower than the acceptable user satisfaction rate. Also during the heuristics evaluation "duplicate orders" was assigned as a major usability problem and in the open-ended survey questions multiple physicians identified duplicate order problem. One of the physician commented:

> "Make it clearer when someone else is active in a chart and ordering a test to avoid double orders"

The finding of duplicate orders in our study and also by the ED physicians needs to be further investigated by the hospital management. It was found to be a problem in our study; however, when discussed with hospital management it was found that the problem was being addressed and that another post CPOE analysis study conducted by the hospital had shown reduction in duplicate orders.

Another major violation was for "minimalist" heuristic where there were too many options for certain laboratory orders to determine which actually causes confusion. In the survey one of the physician commented:

> "Very difficult to search for specialty items b/c of the numerous choices for different exams and labs it was difficult to tell which one to actually order"

Similarly almost most of the problems identified during the heuristics violation were also mentioned by the end-users in the survey.

Limitations

This study has several limitations. First, heuristic evaluation methods do not typically reveal functional issues with user interfaces. Functional issues are mainly issues related to the functionality of the system. Therefore, we did not examine functional issues in detail. Another limitation was that the study did not include observations in the real environment. Third limitation was that due to time constraint we could not look into the details of which of the problems identified were due to vendor coding and which ones were due to facility choices.

Future Work

One area to probe is to develop standards and best practices for the interface design and usability evaluations. There has been a lot of emphasis on including usability evaluation as a part of the certification process of EHR (63), in order to accomplish that we first need to have develop standards for a good interface design (52). This process is underway in the National Institutes of Standards and Technology in 2011. Also performing usability evaluation on various emergency department applications will help us explore what is optimal an interface design of ED application. In this specific study, due to time constraints we could not examine the details about problems that were due to vendor coding and ones that were due to facility tailoring choices. Based on the physicians' comments, we could not conclude whether the CPOE implementation significantly improved workflow or not. A preimplementation and postimplementation comparison study could evaluate if there was any improvement on the workflow or not.

Conclusions

This study revealed a high level of heuristic violations and low physician ratings for user interaction satisfaction. Dealing with an inefficient and unsatisfactory CPOE interface can impede workflow, increase user frustration and affect the clinical quality of care. User feedback should be included during the design phase of an application and the usability evaluation should be performed in the earlier phased of system development. In this particular situation, this high number of usability violations indicates the need for application redesign as well as education of the facility staff and vendor on acceptable usability principles. Institutions and vendors need to employ usability factors when customizing vendors' products. Both the vendors and the facilities should be educated on usability principles and usability evaluations should be completed early in the design and tailoring process. The development of standards and best practices in the system design and usability evaluation should be given high priority.

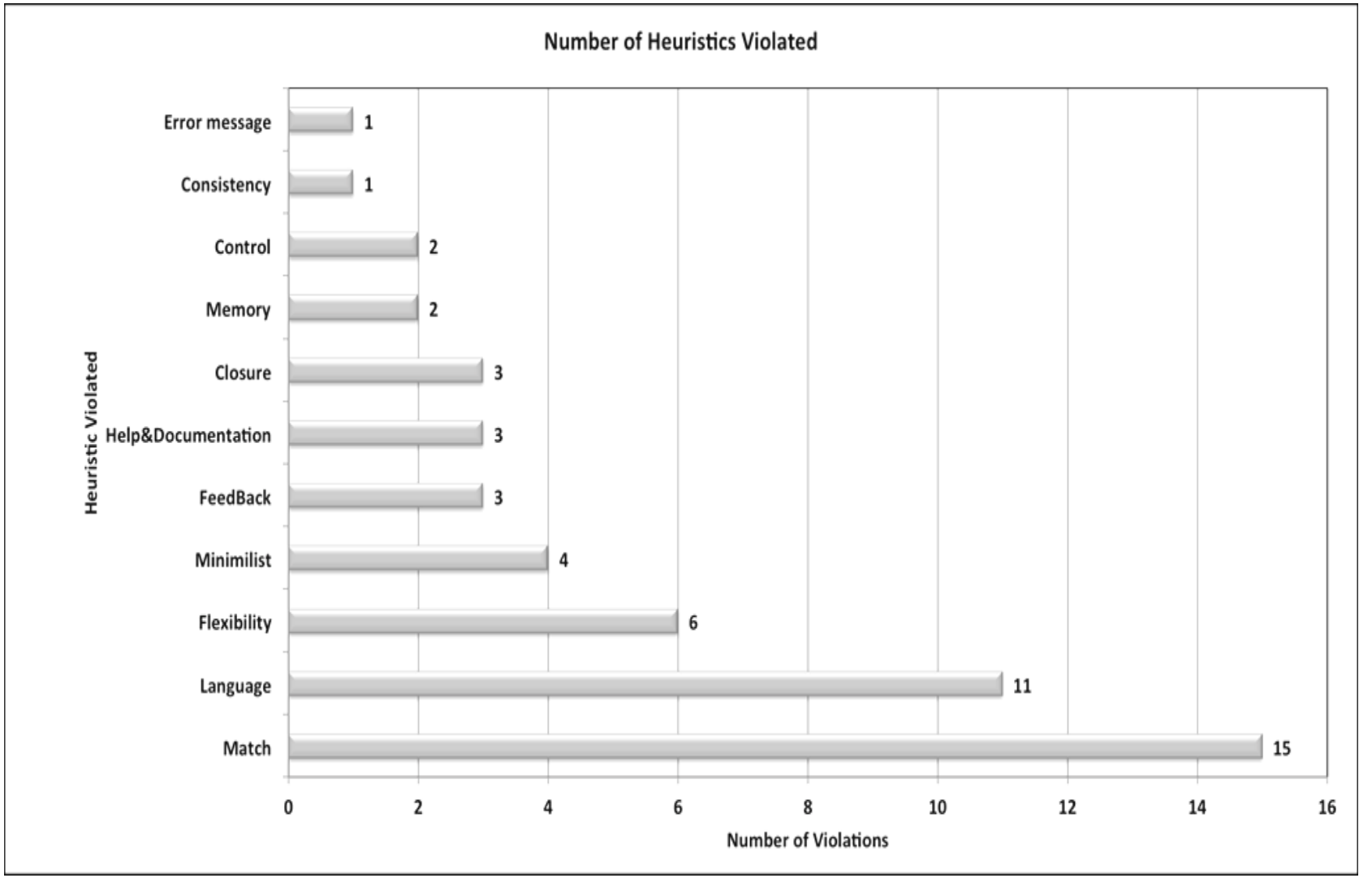

Figure 1. Number of Heuristics Violated

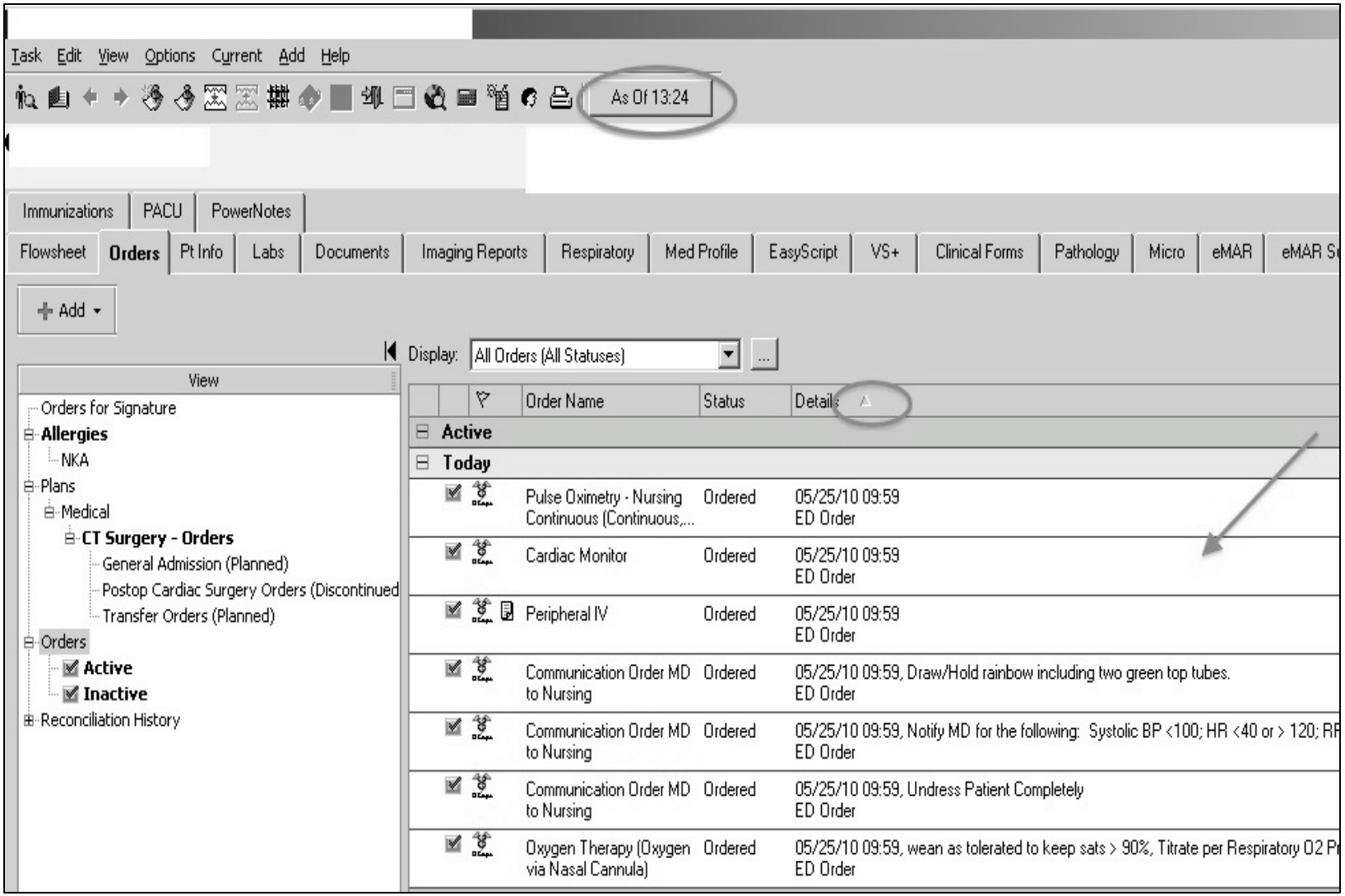

Figure 2. Screen Shot 1: Example of Problem Identified

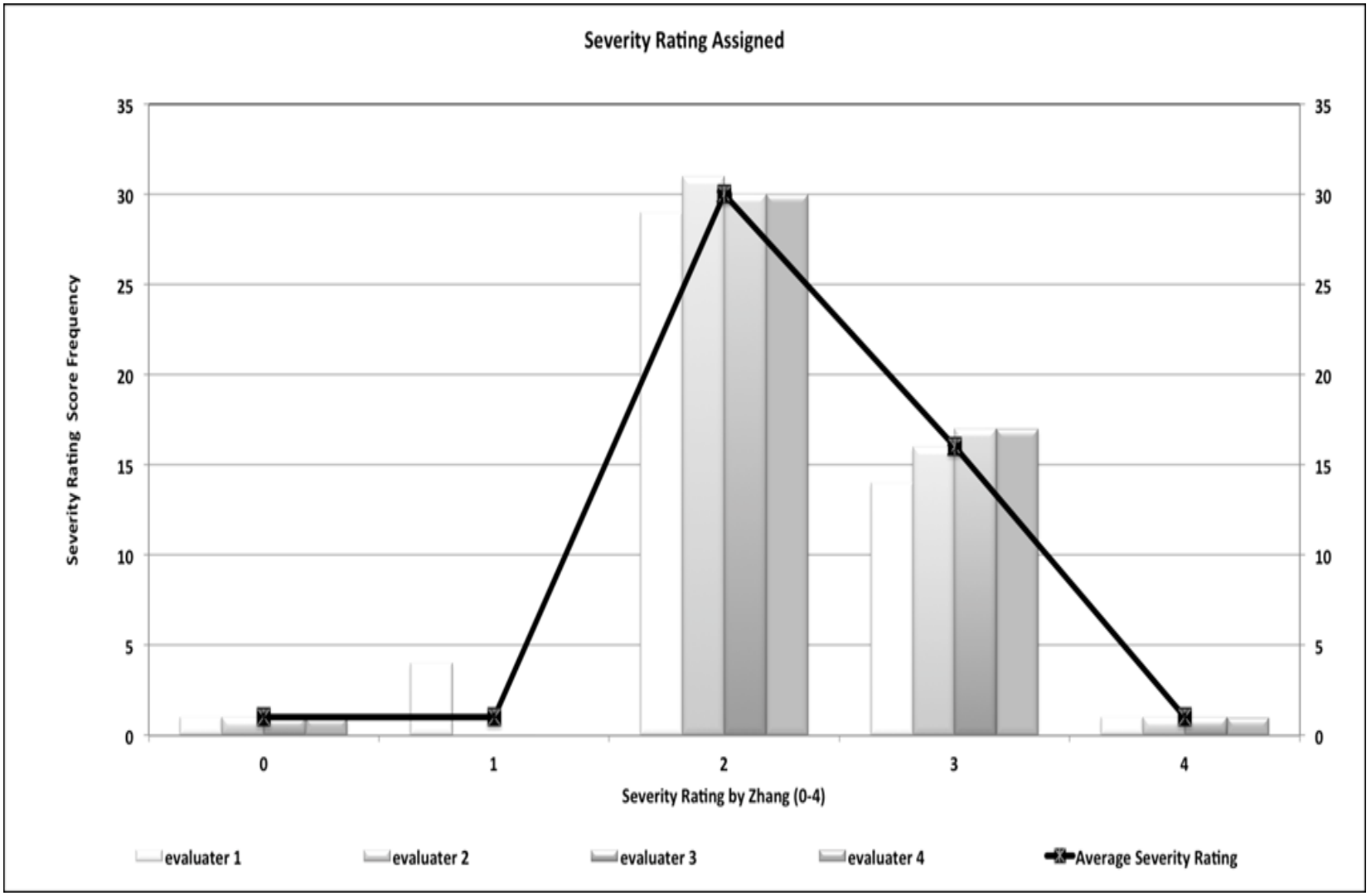

Figure 3. Severity Rating Assigned by Each Evaluator

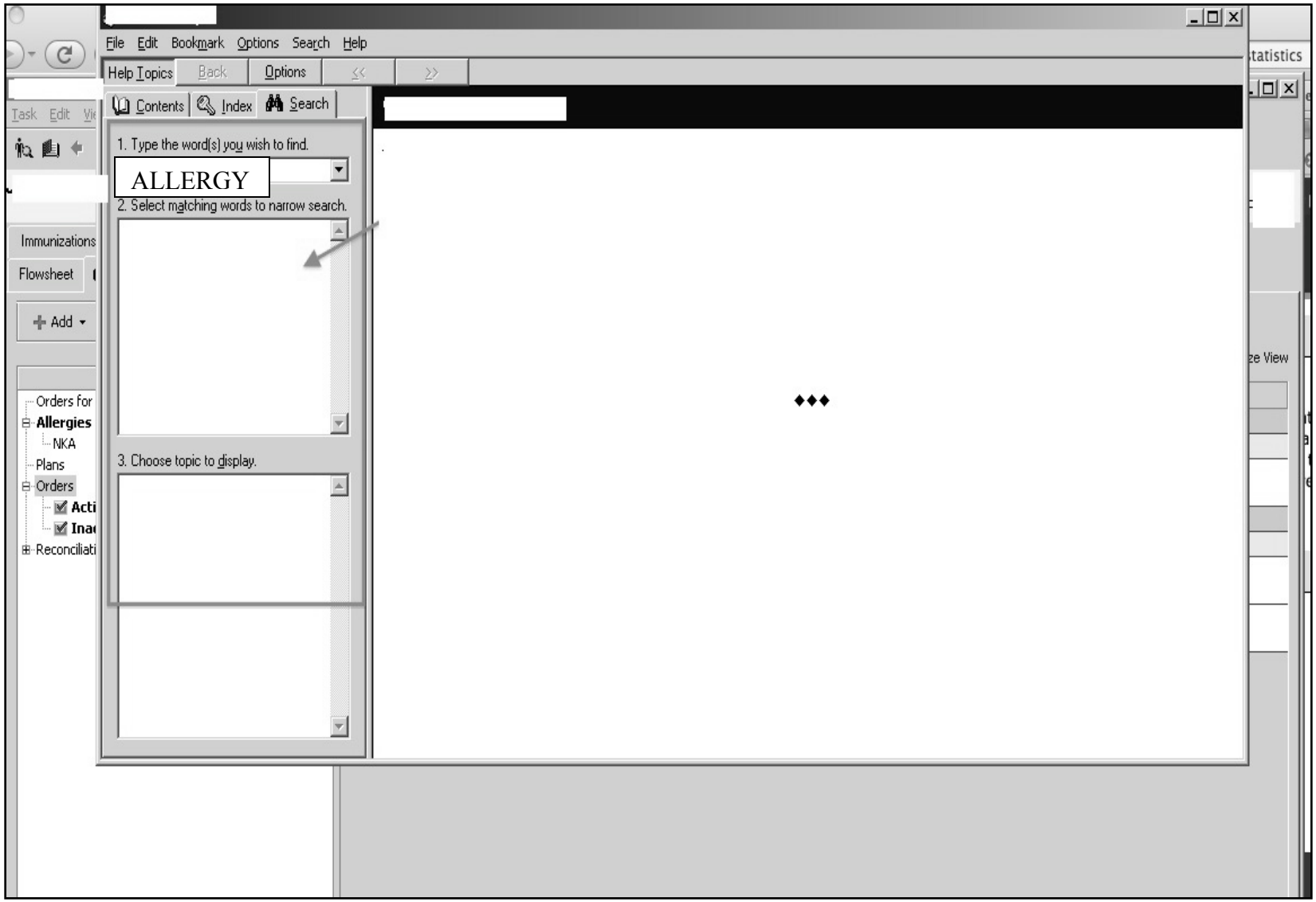

Figure 4. Screen Shot 2: Example of Catastrophic Problem

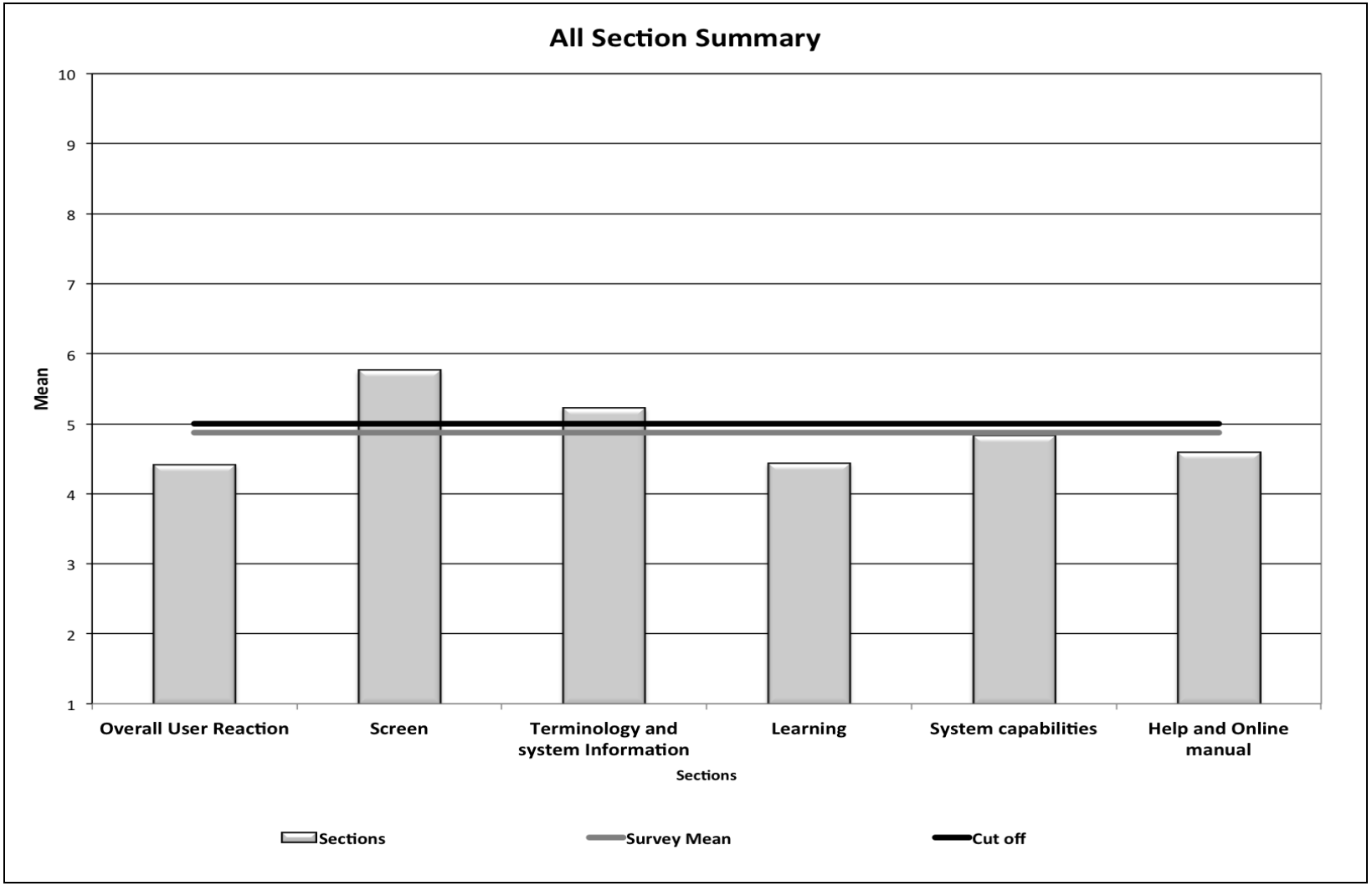

Figure 5. Summary for All Sections

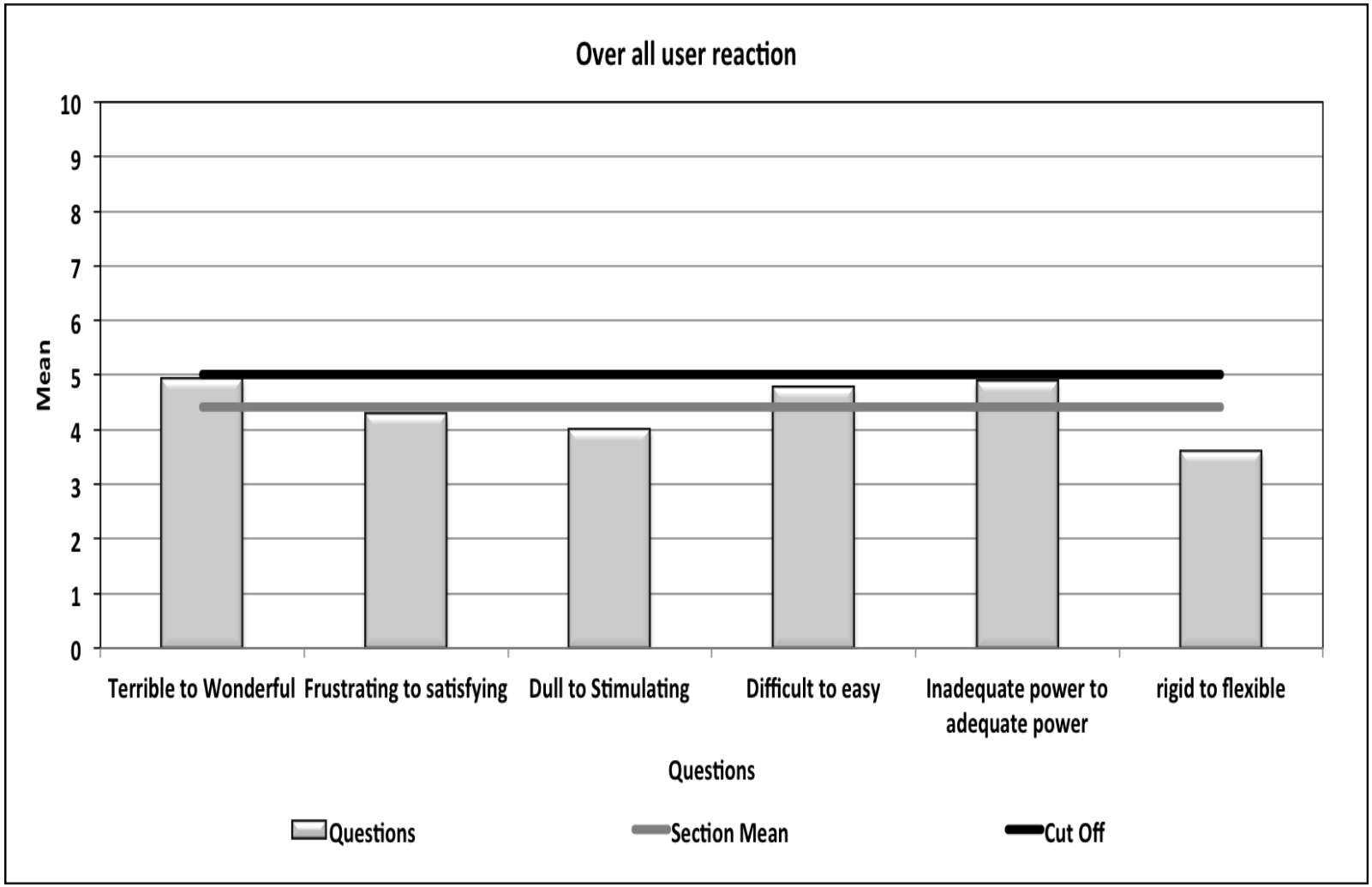

Figure 6. Overall User Reaction

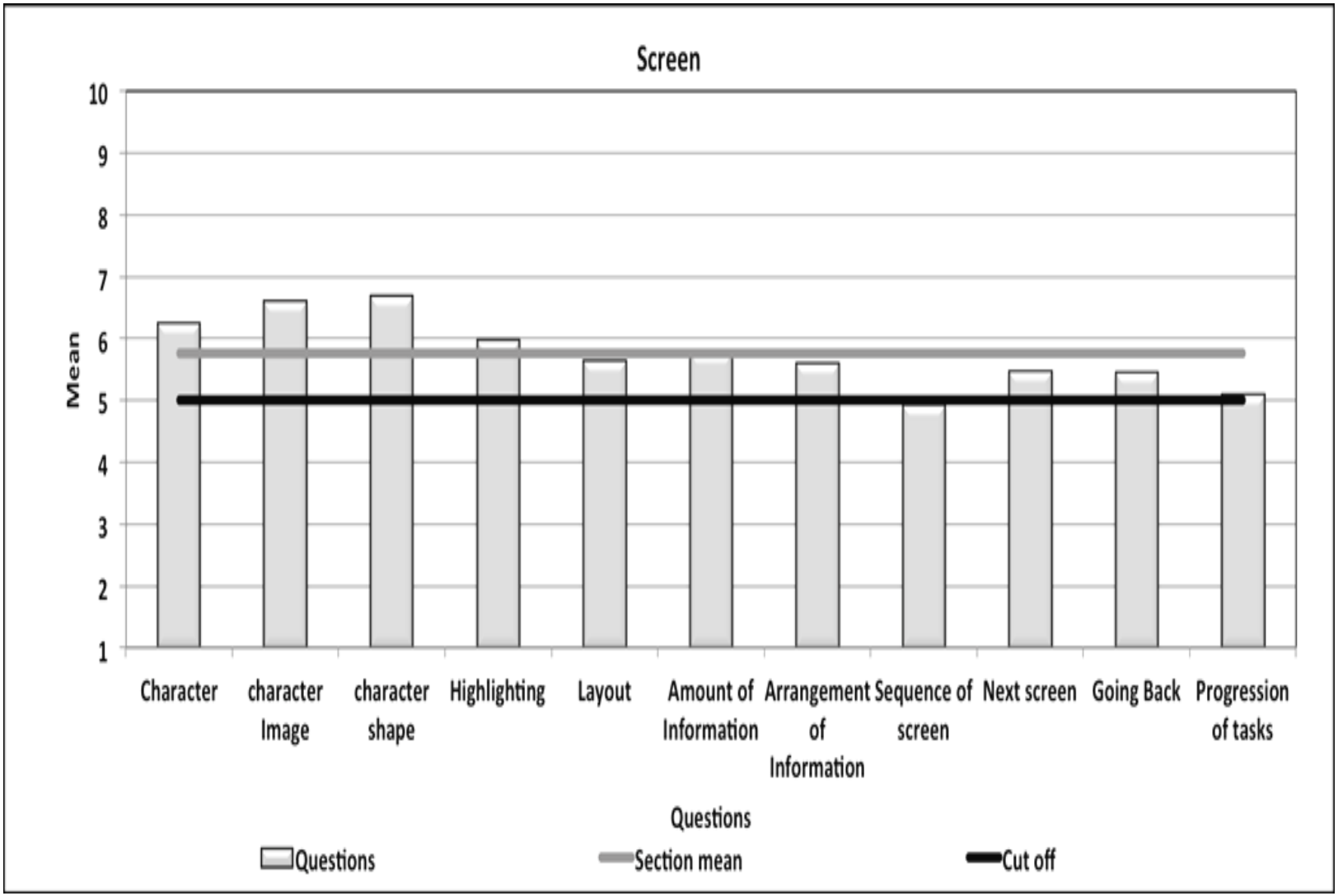

Figure 7. Screen

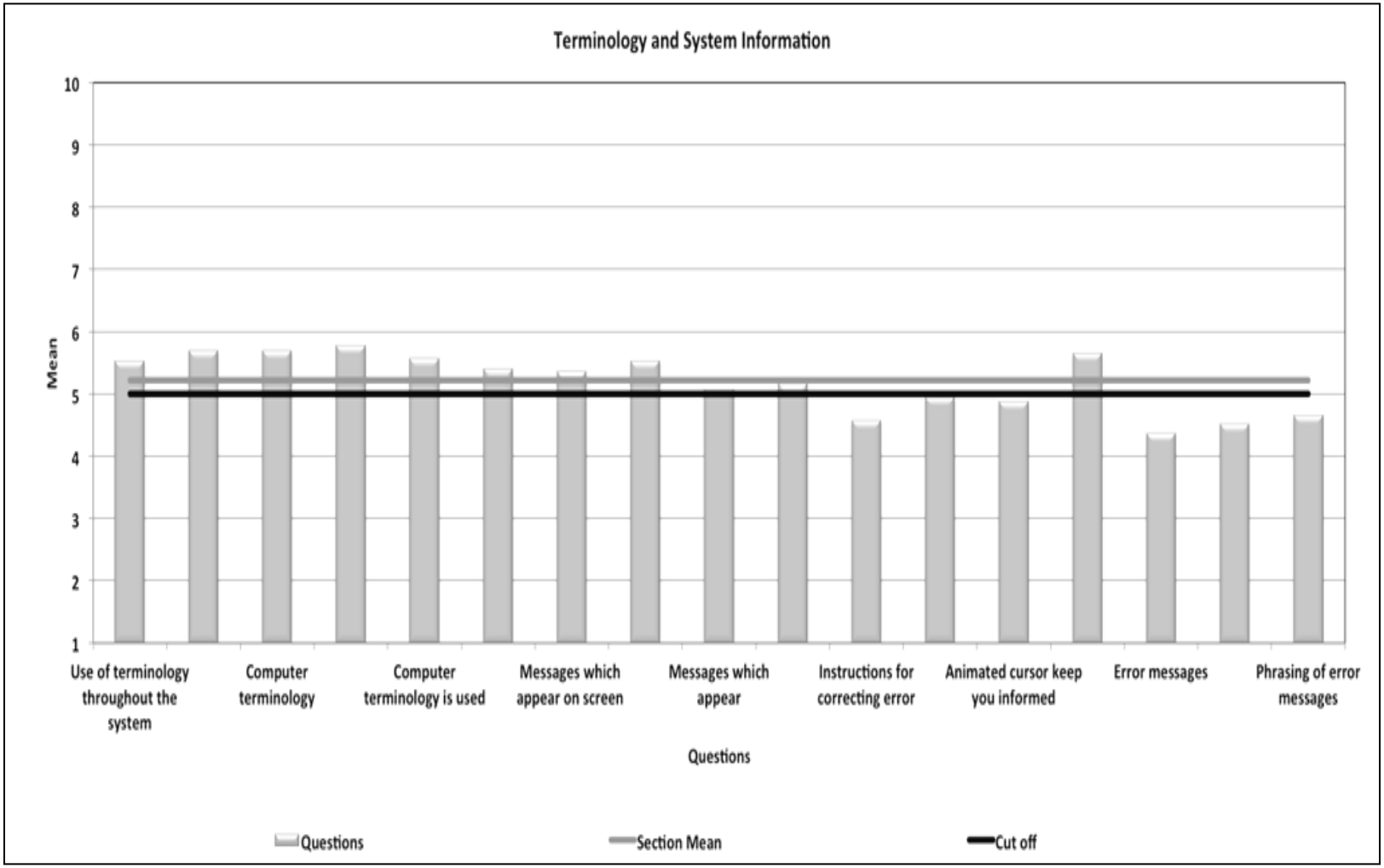

Figure 8. Terminology and System Information

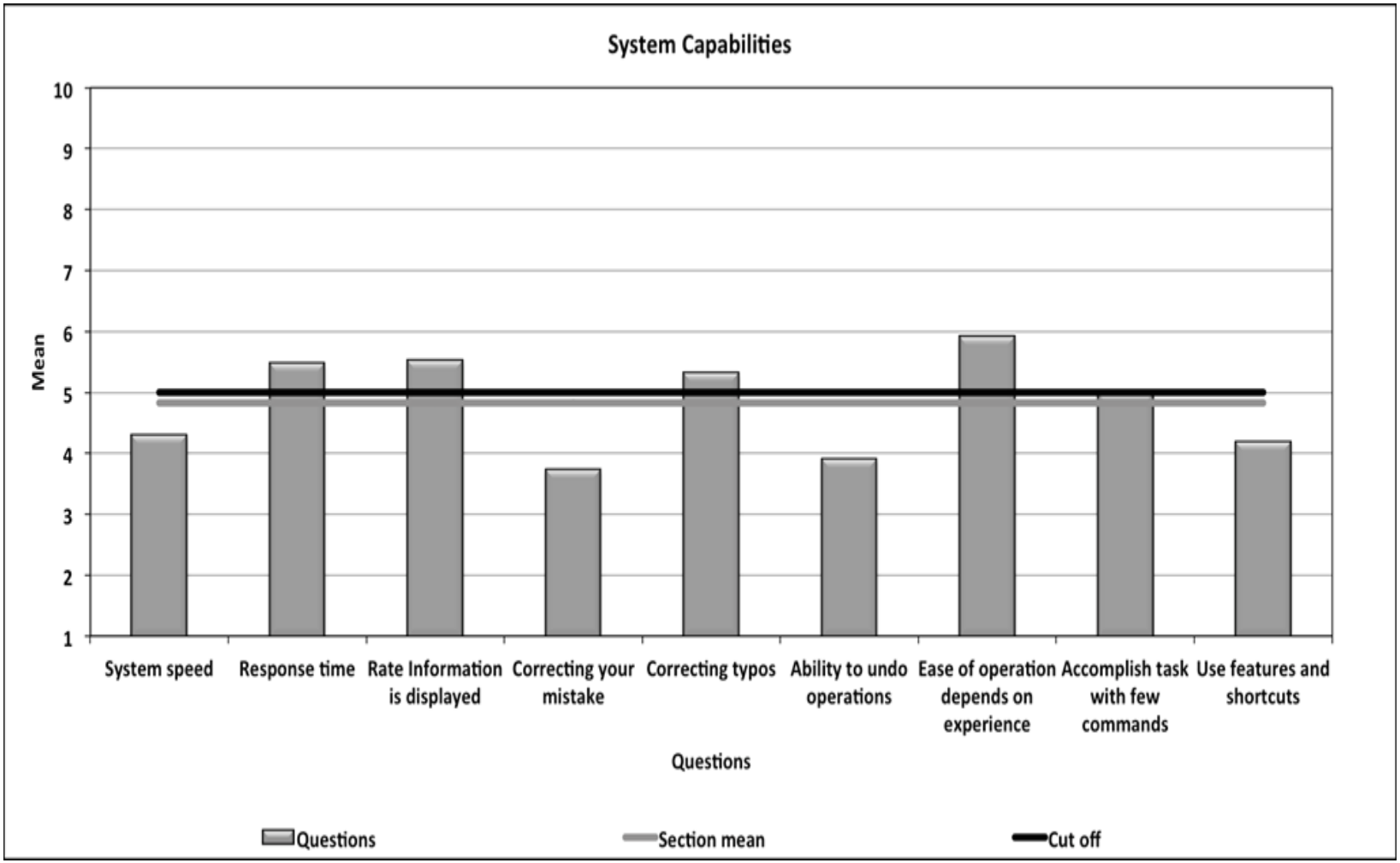

Figure 9. System Capabilities

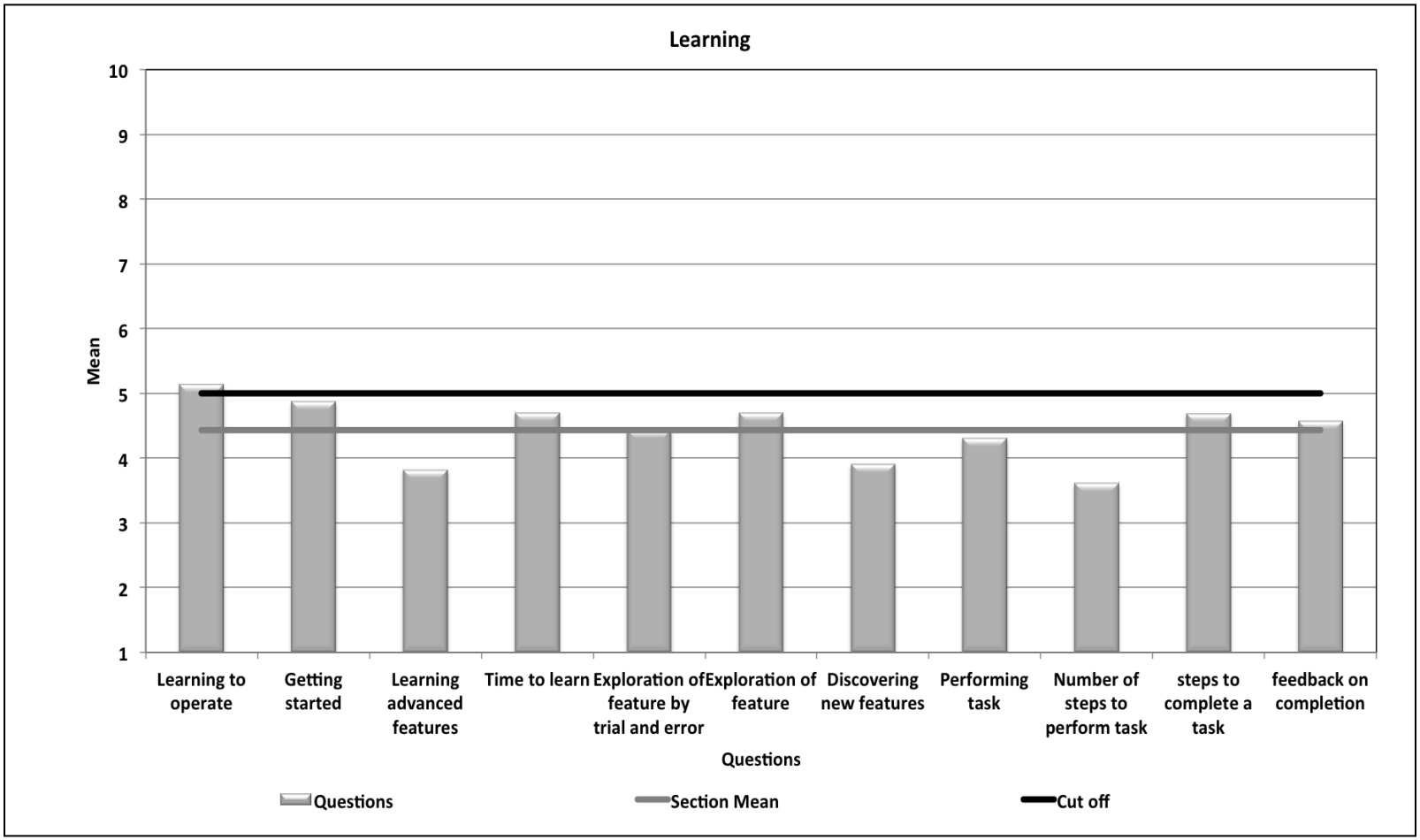

Figure 10. Learning

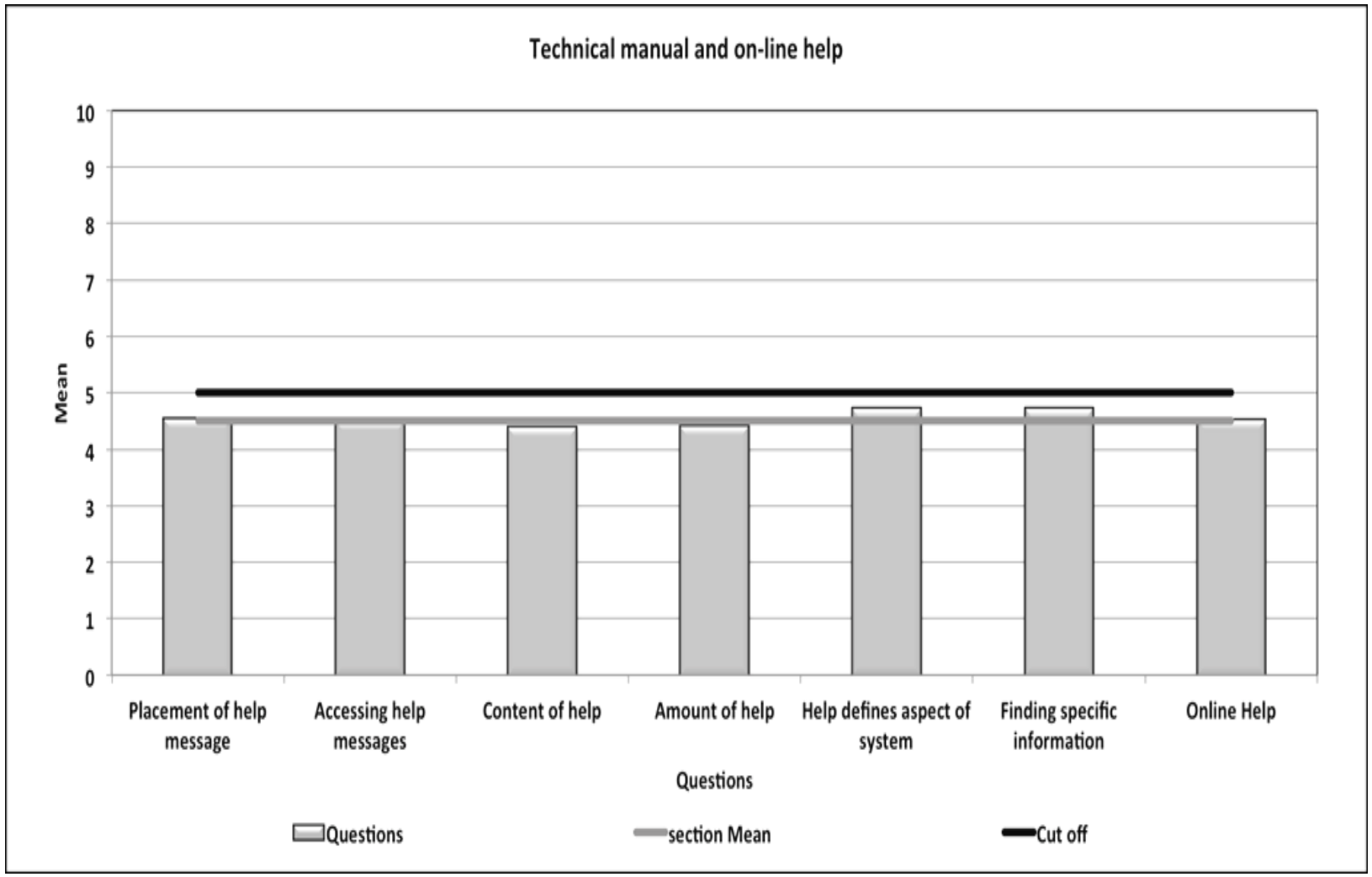

Figure 11. Technical Manual and Help

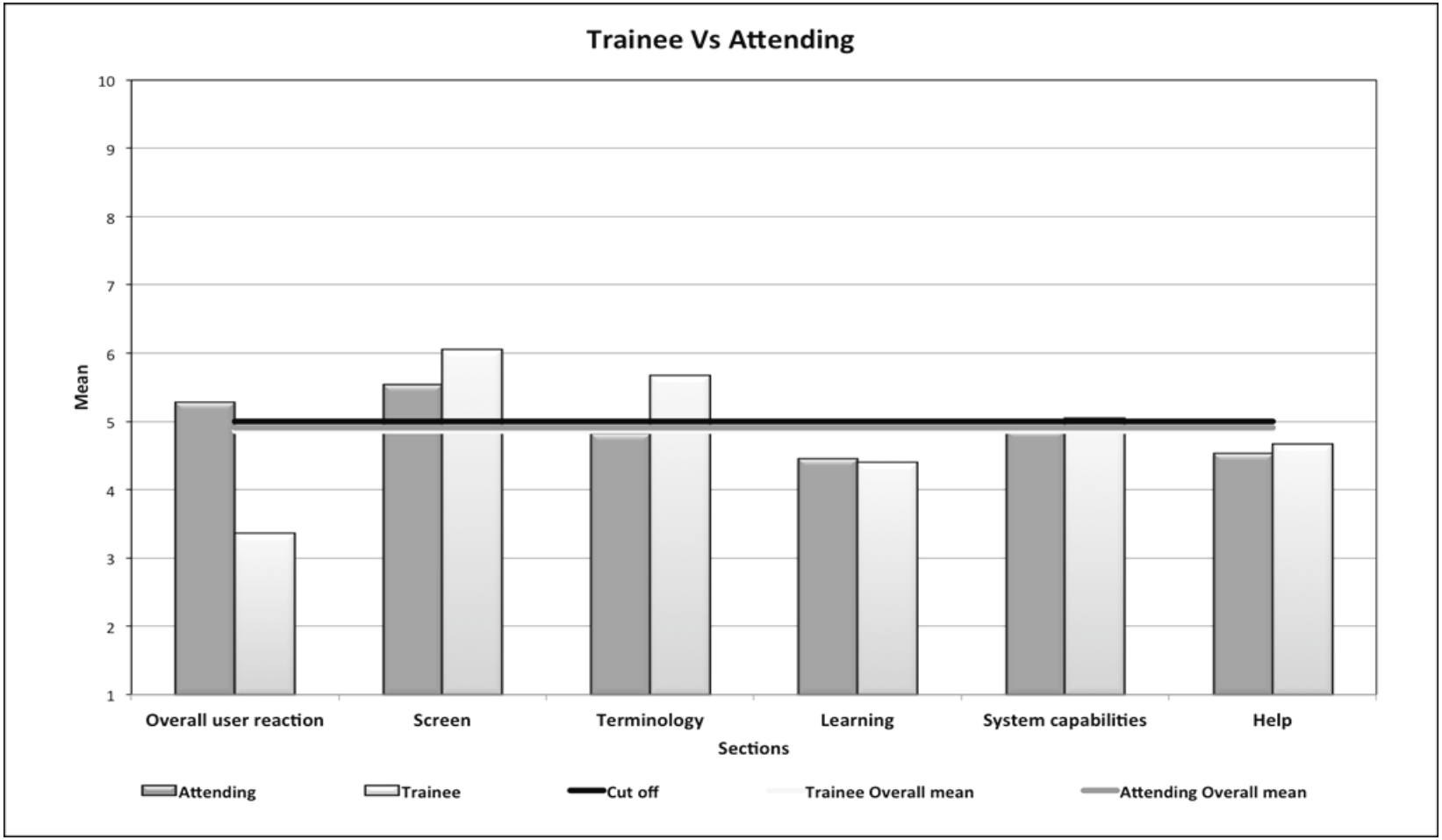

Figure 12. Summary for All Sections—Trainee vs. Attending

Table 1
Fourteen Heuristics of Zhang et al. (7)

	Heuristic	Description
1.	Consistency (consistency and standards)	Users should not have to wonder whether different words, situations or actions mean the same thing. Standard and conventions in product design should be followed. a. Sequences of action (skill acquisition) b. Color (categorization) c. Layout and position (spatial consistency) d. Font, capitalization (levels of organization) e. Terminology (delete, del, remove, rm) and language (words, phrases) f. Standards (e.g., blue underlined text for universal hyperlinks).
2.	Visibility (Visibility of system state)	Users should be informed about what is going on with the system through appropriate feedback and display of information. a. What is the current state of the system? b. What can be done at current state? c. Where can users go? d. What change is made after an action?
3.	Match (match between the system and the world)	The image of the system perceived by users should match the model the users have about the system. a. Users model matches the system image b. Action provided by the system should match actions performed by the user c. Objects on the system should match objects of the task
4.	Minimalist	Any extraneous information is a distraction and a slow down. a. Less is more b. Simple is not equivalent to abstract and general c. Simple is efficient d. Progressive levels of detail

Table 1 continued

	Heuristic	Description
5.	Memory (Minimize memory load)	Users should not be required to memorize a lot of information to carry out tasks. Memory load reduces users capacity to carry out the main tasks. a. Recognition vs. recall (e.g. menu vs. commands) b. Externalize information through visualization. c. Perceptual procedures d. Hierarchical structure e. Default values f. Concrete examples (DD/MM/YY, e.g. 10/20/99) g. Generic rules and actions (e.g., drag objects).
6.	Feedback (Informative feedback)	Users should be given prompt and informative feedback about their actions a. Information that can be directly perceived, interpreted, and evaluated b. Levels of feedback (novice and expert) c. Concrete and specific, not abstract and general. d. Response time: 0.1s for instanteously reacting 1.0s for uninterrupted flow of thoughts 10s for the limit of attention
7.	Flexibility (Flexibility and efficiency)	Users always learn and users are always different. Give users the flexibility of creating customization and shortcuts to accelerate their performance. a. Shortcuts for experienced users b. Shortcuts or macros for frequently used operations c. Skill acquisition through chunking d. Examples: e. Abbreviations, function keys, hot keys, command keys, macros, aliases, templates, type-ahead, bookmarks, hot links, history, default values, etc.

Table 1 continued

	Heuristic	Description
8.	Message (Good error messages)	The messages should be informative enough such that users can understand the nature of errors, learn from errors, and recover from errors. a. Phrased in clear language, avoid obscure codes. Example of obscure code: “system crashed, error code 147”. b. Precise not vague or general. Example of general comment: “Cannot open document” c. Constructive. d. Polite. Examples of impolite message: “illegal user action,” “job aborted”, “system was crashed”, “fatal error”, etc
9.	Error (Prevent errors)	It is always better to design interfaces that prevent errors from happening in the first place. a. Interfaces that make error impossible b. Avoid modes (e.g. vi, text wrap). Or use informative feedback, e.g., different sounds. c. Execution error vs. evaluation error. d. Various types of slips and mistakes
10.	Closure (Clear closure)	Every task has a beginning and an end. Users should be clearly notified about the completion of a task. a. Clear beginning, middle, and end. b. Complete 7-stages of actions. c. Clear feedback to indicate goals are achieved and currents stacks of goals can be released. Examples of good closures include many dialogues
11.	Undo (Reversible actions)	Users should be allowed to recover from errors. Reversible actions also encourage exploratory learning. a. At different levels: a single action, a subtask, or a complete task. b. Multiple steps. c. Encourage exploratory learning d. Prevent serious errors.

Table 1 continued

	Heuristic	Description
12.	Language (Use users language)	The language should be always presented in a form understandable by the intended users. a. Use standard meanings of words. b. Specialized language for specialized group c. User defined aliases. d. Users' perspective. Example: "we have bought four tickets for you" (bad) vs. "you bought four tickets" (good)
13.	Control (user in control)	DO not give users that impression that they are controlled by the systems. a. Users are initiators of actors, not responders to actions. b. Avoid surprising actions, unexpected outcomes, tedious sequences of actions, etc
14.	Document (help and documentation)	Always provide help when needed. a. Context-sensitive help b. Four types of help - Task-oriented - Alphabetically ordered; - Semantically organized; - Search. c. Help embedded in contents.

Table 2

List of the Emergency Department Tasks

No.	List of the Tasks provided to the evaluator's
1.	Order Blood Products
2.	Order Medication (Ativan)
3.	Modify an order
4.	Cancel an order
5.	Add an allergy
6.	Create a plan
7.	Search for help
8.	Signing orders
9.	Order a lab
10.	Trauma order set
11.	Look up Patient History
12.	Color coding for critical values
13.	Chronological order of orders
14.	Specific order for sinus x-ray
15.	Order IV fluids
16.	Restraining order
17.	Order drug screen -carbamazepine level
18.	ETOH level
19.	O2 saturation
20.	Order ABG
21.	Order CT scan
22.	Order MRI
23.	Creating a Favorite folder

Table 3

Zhang et al. Severity Score

The heuristics are used to check the interface of the device design. If a heuristic is violated, it is given a severity rating based on the following scales:

Rating	Severity
0	Not a usability problem at all.
1	Cosmetic problem only. Need not be fixed unless extra time is available.
2	Minor usability problem. Fixing this should be given low priority.
3	Major usability problem. Important to fix, should be given high priority.
4	Usability catastrophe. Imperative to fix this before product can be released.

Table 4

Sample Heuristics Violations/Problems Identified

	Task	Usability Problem	Heuristics Violated	Evaluator 1	Evaluator 2	Evaluator 3	Evaluator 4
1	Add an allergy	Too much information color coded in red on screen	Minimalist	2	2	2	2
		Forces the user to choose a category which should be mapped/ not clear on how to find the codified symptoms	Match	2	2	2	2
		Creating an allergy the steps do not have a clear feedback	Feedback	2	2	2	2
2	Sign a order	Cannot sign individual order	Flexibility	3	3	3	3
			Control	3	3	3	3
3	Search for Help	Typed in "allergy" nothing shows up	Document	4	4	4	4

Table 4 continued

	Task	Usability Problem	Heuristics Violated	Evaluator 1	Evaluator 2	Evaluator 3	Evaluator 4
4	O2 Saturation	Oximetry is ok but o2 sat cannot be searched	Language	2	2	2	2
		Looked for O2 stat, SpO2, Oxygen but could not find anything	Match	2	3	3	3
5	Order IV fluids	7 clicks to place the order	Flexibility	3	3	3	3
		Could not back up	Flexibility	2	2	3	3
6	Order an ABG	Ambiguous	Document	2	2	2	2
		Allows duplicate orders	Error	3	3	3	3
7	Order a Blood Product	Too much Information and Icons	Minimalist	2	2	2	2
8		Need to refresh every time you order, and cannot find the refresh icon	Match	3	3	3	3

Tables 5

Violation under each Heuristic

Total Number of Problems Found										
48										
Violations under each Heuristic										
Match	**Language**	**Flexibility**	**Minimalist**	**Feed**	**Back**	**Help**	**Closure**	**Memory**	**Control**	**Consistency**
15	11	6	4	3	3	3	2	2	1	1

Total Number of Heuristics Violated	
51	

Table 6

Severity Rating assigned by each evaluator

Total Number of Task Given	**Fleis' Kappa**
23	0.81

Severity Rating assigned by each evaluator					
Rating Score	Total	Evaluator1	Evaluator2	Evaluator3	Evaluator4
0	4	1	1	1	1
1	4	4	0	0	0
2	120	29	31	30	30
3	64	14	16	17	17
4	4	1	1	1	1

Table 7

Demographics of the Sample

	Interns	Resident Year 1	Resident Year 2	Resident Year 3	Fellow	Attending
Total	9	15			5	21
Responses	4/9	0	3	3	1/5	14/21
Average Age	27.75	NA	31	30.66		44.16
Average Years Practicing Medicine	2.16	NA	2	6	4	16.14
Average Years worked in ED	0.9	NA	2	3	4	14.35
Average Years worked in the University Hospital	0.9	NA	2	3.6	4	10.32
Months/Years worked on ED CPOE	1.16	NA	0.7	2.56	1.5	0.7
Average time spent working on ED CPOE	> 10 hrs	NA	> 10 hrs	> 10 hrs	B/w 1-4 hrs	>10 hrs (majority)
Other EHR/EMR worked on	50%= 1 system, 50%=2 systems	NA	75%=1 system, 25%=2 systems	75%=more than 3 systems, 25%= 3 systems	100%= 2 systems	28%=none,28% =1 system, 21%= 2 systems, 14%= 3 systems and 7%=more than 3 systems.

Table 8

Overall Descriptive Statistics

Section	Mean	Standard Deviation	Upper Confidence Interval	Lower Confidence Interval	Standard Deviation of XBar
Overall Average	4.86	1.74	5.22	4.50	0.17
Overall User reaction	4.50	1.70	4.77	4.22	0.14
Screen	5.76	1.59	5.95	5.26	0.10
Terminology and system Information	5.12	1.49	5.26	4.97	0.07
Learning	4.43	1.67	4.64	4.23	0.11
System Capabilities	4.83	1.77	5.35	4.30	0.12
Technical Manual and Help	4.59	1.50	4.84	4.35	0.12

Table 9

Descriptive Statistics for the Trainee

Section	Mean	Standard Deviation	Upper Confidence Interval	Lower Confidence Interval	Standard Deviation Of XBar
Overall Average	4.09	1.44	4.37	3.80	0.13
Overall User reaction	3.36	1.91	3.82	2.90	0.23
Screen	6.05	1.66	6.35	5.75	0.15
Terminology and system Information	5.67	1.28	5.86	5.49	0.09
Learning	4.40	1.92	4.76	4.03	0.18
System Capabilities	5.04	1.89	5.44	4.64	0.20
Technical Manual and Help	4.66	1.83	5.10	4.22	0.22

Table 10

Descriptive Statistics for the Attending

Section	Mean	Standard Deviation	Upper Confidence Interval	Lower Confidence Interval	Standard Deviation Of XBar
Overall Average	4.91	1.48	5.09	4.56	0.13
Overall User reaction	5.28	1.60	5.12	4.43	0.17
Screen	5.53	1.48	5.76	5.29	0.12
Terminology and system Information	4.82	1.56	5.03	4.61	0.10
Learning	4.45	1.47	4.70	4.21	0.12
System Capabilities	4.86	1.65	5.16	4.55	0.15
Technical Manual and Help	4.53	1.15	4.78	4.27	0.12

Table 11

Analysis of Variance (ANOVA)

Multiple Factor with Interaction

Source of Variation	SS	df	MS	F	P
Fx=sections	440.3	5	88.06	30.66	<2.2e-16***
Fz=experience level	10.8	1	10.79	3.75	0.052
Fx:fz	160.2	5	32.04	11.15	1.439e-10***

Table 12

TukeyHSD

TukeyHSD: multiple comparisons of means
95% family-wise confidence level
Where:
Fx= Each Section
Fz=Experience level
1= Trainee's (interns, residents, fellows), 2= Attending, 3= Overall user reaction, 4=Screen, 5= terminology and system information, 6= system capabilities, 7= learning, 8= technical manual and help

Fx:Fz	*Diff*	*Lower*	*Upper*	*P-adj*
3:2-3:1	1.46	0.60	2.33	0.000002
4:2-4:1	-0.49	-1.17	0.18	0.40
5:2-5:1	-0.79	-1.34	-0.23	0.00019
6:2-6:1	0.07	-0.63	0.78	0.99
7:2-7:1	-0.16	-0.95	0.61	0.99
8:2-8:1	-0.16	-1.07	0.7	0.99

CHAPTER 4

CONCLUSION

From this study we concluded that the current is an example of a poorly designed application. This application violates all the three goals of usability assessment: 1) Effectiveness, 2) Efficiency and 3) User Satisfaction. Such an application could cause an increase in error rates, lead to poor clinical workflow and have an impact on patient safety. U.S. regulatory bodies need to make sure that the vendors and the facilities implementing the application are educated on the usability principles. Vendors need to make sure that usability evaluation is conducted in the early design phase of application development cycle and end-user feedback is considered while designing/customizing these systems. In general, heuristic evaluation was found to be a very cost effective and accurate method of identifying usability problems when applied on an ED CPOE application. The combined use of an expert based inspection method and user based assessment was very successful; it was interesting to observe the results obtained from the latter evaluation supported the results obtained from the former. There were gaps identified regarding the best practices and standards for a good interface design and usability evaluation during the various phases of development cycle that need to be filled.

Significance to Biomedical Informatics

Cognitive sciences, human factors analysis, usability engineering and usability evaluation have been recognized as important areas in the field of informatics. Academia

has understood the importance of human factors. Even in the research world it is well known that a good interface design is directly proportional to end-user satisfaction as well adoption of a clinical system. However, the applied arena of informatics is still struggling to understand the importance of human factors in general and usability in specific.

This research is a significant contribution to the field of informatics and serves as a translation between research and informatics practice. In IT operations, it helps in understanding the problems associated with a poor interface design and its potential impact on the workflow, end-user satisfaction and patient safety. The findings of this research study has highlighted several important factors (poor interface design), that once resolved can lead to an improvement in end-user adoption of systems and using them meaningfully, to the benefit of the facility and the patient. This is the current goal of the regulatory bodies and the government of United States. This study points to a very important issue especially for the informatics research community and that is developing best practices and standards for interface design and usability evaluation monitoring during different phases of system development cycle. The use of a "unique" combination of expert based inspection method the Zhang et al. heuristic evaluation, with a user assessment with the "Questionnaire of user interaction satisfaction" resulted in a successful evaluation of the application. It sets a roadmap for future evaluation of other systems by using the combination of above-mentioned methods.

Future Work

This project by no means is the end; it is the beginning of a major initiative towards the importance of learning and conducting usability evaluation by not only the

vendors but also academia and the facilities involved. A substantial amount of work needs to be done in this area. One important area to explore is the best practices and standards for a good interface design and usability evaluation monitoring at various phases of system development. To perform a comparative analysis by using similar methods on other available similar application, this will also help us understand various interfaces and eventually help in developing best practices and standards.

APPENDIX A

ELECTRONIC VERSION OF QUESTIONNAIRE OF USER INTERACTION SURVEY

1. Introduction to the Survey

Dear Participant,

This is a survey to evaluate the Cerner FirstNet Emergency Department Computerized Physician Order Entry(CPOE) system. This survey will take approximately 5 minutes to complete. This survey is about the general characteristics of the CPOE module interface. Your feedback on the interface will be highly appreciated and the results of this survey will be used as a part of a research being conducted at the Department of Biomedical Informatics (DBMI), School Of Medicine at University of Utah.

Thank you!

Sincerely,

Neelam Zafar, MD, MHA

2. General Information

General/demographic Information

1. Your Age?

2. Please select your exact position:

- ○ Intern
- ○ Resident Year 1
- ○ Resident Year 2
- ○ Resident Year 3
- ○ Fellow
- ○ Attending

Other (please specify)

3. How long have you been practicing medicine?

4. How long have you worked in the ED?

5. How long have you worked at the University Hospital?

6. System experience: How long have you used the ED CPOE system?

7. On the average, how much time do you spend per week on the ED CPOE system?

- ○ Less than 1 hour
- ○ One to less than 4 hours
- ○ 4 to less than 10 hours
- ○ Over 10 hours

Other (please specify)

8. Past Experience: How many other ED/Hospital/EMR systems have you worked with?

- ○ None
- ○ 1
- ○ 2
- ○ 3
- ○ more than 3

Other (please specify)

[ ]

3. Overall User Reaction

Please rate your over all impression of FirstNet CPOE module in ED. Please circle the numbers which most appropriately reflect your impressions about using the ED CPOE module on a scale of 1-9. Not Applicable = NA.

1. Terrible to wonderful

	1= Terrible	2	3	4	5	6	7	8	9= Wonderful	NA
A.	○	○	○	○	○	○	○	○	○	○

2. Frustrating to Satisfying

	1= Frustrating	2	3	4	5	6	7	8	9= Satisfying	NA
B.	○	○	○	○	○	○	○	○	○	○

3. dull to stimulating

	1=dull	2	3	4	5	6	7	8	9=stimulating	NA
C.	○	○	○	○	○	○	○	○	○	○

4. difficult to easy

	1=difficult	2	3	4	5	6	7	8	9=easy	NA
D.	○	○	○	○	○	○	○	○	○	○

5. Inadequate power to Adequate Power

	1=Inadequate	2	3	4	5	6	7	8	9=adequate	NA
E.	○	○	○	○	○	○	○	○	○	○

6. rigid to flexible

	1=rigid	2	3	4	5	6	7	8	9= flexible	NA
F.	○	○	○	○	○	○	○	○	○	○

4. Screen

Please share your experience with the screen layout of Cerner FirstNet CPOE module by answering the questions listed below.Please circle the numbers which most appropriately reflect your impressions about using the ED CPOE module on a scale of 1-9. Not Applicable = NA.

1. Characters on the computer screen

	1= Difficult to read	2	3	4	5	6	7	8	9= Easy to read	NA
A.	○	○	○	○	○	○	○	○	○	○

2. Image of characters

	1= Fuzzy	2	3	4	5	6	7	8	9= Sharp	NA
B.	○	○	○	○	○	○	○	○	○	○

3. Character Shapes(Fonts)

	1= Barely legible	2	3	4	5	6	7	8	9= Very Legible	NA
C.	○	○	○	○	○	○	○	○	○	○

4. Highlighting on the screen

	1= Unhelpful	2	3	4	5	6	7	8	9= Helpful
D.	○	○	○	○	○	○	○	○	○

5. Screen layouts were helpful

	1= Never	2	3	4	5	6	7	8	9= Always	NA
E.	O	O	O	O	O	O	O	O	O	O

6. Amount of information that can be displayed on screen

	1= Inadequate	2	3	4	5	6	7	8	9= Adequate	NA
F.	O	O	O	O	O	O	O	O	O	O

7. Arrangement of information on screen

	1= Illogical	2	3	4	5	6	7	8	9= Logical	NA
G.	O	O	O	O	O	O	O	O	O	O

8. Sequence of screens

	1= Confusing	2	3	4	5	6	7	8	9= Clear	NA
H.	O	O	O	O	O	O	O	O	O	O

9. Next screen in a sequence

	1= Unpredictable	2	3	4	5	6	7	8	9= Predictable	NA
I.	O	O	O	O	O	O	O	O	O	O

10. Going back to the previous screen

	1= Impossible	2	3	4	5	6	7	8	9= Easy	NA
J.	○	○	○	○	○	○	○	○	○	○

11. Progression of work related tasks

	1= Confusing	2	3	4	5	6	7	8	9= Clearly Marked	NA
K.	○	○	○	○	○	○	○	○	○	○

12. Please write your comments about the screens here:

5. Terminology and System Information

Please share your experience with the wording that is used in the CPOE module by answering the questions listed below. Please circle the numbers which most appropriately reflect your impressions about using the ED CPOE module on a scale of 1-9. Not Applicable = NA.

1. Use of terminology throughout system

	1= Inconsistent	2	3	4	5	6	7	8	9= Consistent	NA
A.	O	O	O	O	O	O	O	O	O	O

2. Work related terminology

	1= Inconsistent	2	3	4	5	6	7	8	9= Consistent	NA
B.	O	O	O	O	O	O	O	O	O	O

3. Computer terminology

	1= Inconsistent	2	3	4	5	6	7	8	9= Consistent	NA
C.	O	O	O	O	O	O	O	O	O	O

4. Terminology relates well to the work you are doing?

	1= Always	2	3	4	5	6	7	8	9= Never	NA
D.	O	O	O	O	O	O	O	O	O	O

5. Computer terminology is used

	1= Too Frequently	2	3	4	5	6	7	8	9= Appropriately	NA
E.	O	O	O	O	O	O	O	O	O	O

6. Terminology on the screen

	1= Ambiguous	2	3	4	5	6	7	8	9= Precise	NA
F.	O	O	O	O	O	O	O	O	O	O

7. Messages which appear on screen

	1= Inconsistent	2	3	4	5	6	7	8	9= Consistent	NA
G.	O	O	O	O	O	O	O	O	O	O

8. Position of instructions on the screen

	1= Inconsistent	2	3	4	5	6	7	8	9= Consistent	NA
H.	O	O	O	O	O	O	O	O	O	O

9. Messages which appear on screen

	1= Confusing	2	3	4	5	6	7	8	9= Clear	NA
I.	O	O	O	O	O	O	O	O	O	O

10. Instructions for commands or functions

	1= Confusing	2	3	4	5	6	7	8	9= Clear	NA
J.	○	○	○	○	○	○	○	○	○	○

11. Instructions for correcting errors

	1= Confusing	2	3	4	5	6	7	8	9= Clear	NA
K.	○	○	○	○	○	○	○	○	○	○

12. Computer keeps you informed about what it is doing

	1= Never	2	3	4	5	6	7	8	9= Always	NA
L.	○	○	○	○	○	○	○	○	○	○

13. Animated cursors keep you informed

	1= Never	2	3	4	5	6	7	8	9= Always	NA
M.	○	○	○	○	○	○	○	○	○	○

14. Performing an operation leads to a predictable result

	1= Never	2	3	4	5	6	7	8	9= Always	NA
N.	○	○	○	○	○	○	○	○	○	○

15. Error messages

	1= Unhelpful	2	3	4	5	6	7	8	9= Helpful	NA
O.	○	○	○	○	○	○	○	○	○	○

16. Error messages clarify the problem

	1= Never	2	3	4	5	6	7	8	9= Always	NA
P.	○	○	○	○	○	○	○	○	○	○

17. Phrasing of error messages

	1= Unpleasant	2	3	4	5	6	7	8	9= Pleasant	NA
Q.	○	○	○	○	○	○	○	○	○	○

18. Please write your comments about terminology and system information here:

6. Learning

Please share your learning curve for the Cerner FirstNet ED CPOE module.Please circle the numbers which most appropriately reflect your impressions about using the ED CPOE module on a scale of 1-9. Not Applicable = NA.

1. Learning to operate the system

	1= Difficult	2	3	4	5	6	7	8	9= Easy	NA
A.	○	○	○	○	○	○	○	○	○	○

2. Getting started with the system

	1= Difficult	2	3	4	5	6	7	8	9= Easy	NA
B.	○	○	○	○	○	○	○	○	○	○

3. Learning advanced features about the system

	1= Difficult	2	3	4	5	6	7	8	9= Easy	NA
C.	○	○	○	○	○	○	○	○	○	○

4. Time to learn to use the system

	1= Slow	2	3	4	5	6	7	8	9= Fast	NA
D.	○	○	○	○	○	○	○	○	○	○

5. Exploration of features by trial and error

	1= Discouraging	2	3	4	5	6	7	8	9= Encouraging	NA
E.	○	○	○	○	○	○	○	○	○	○

6. Exploration of features

	1= Risky	2	3	4	5	6	7	8	9= Safe	NA
F.	○	○	○	○	○	○	○	○	○	○

7. Discovering new features

	1= Difficult	2	3	4	5	6	7	8	9= easy	NA
G.	○	○	○	○	○	○	○	○	○	○

8. Tasks can be performed in a straight-forward manner

	1= Never	2	3	4	5	6	7	8	9= Always	NA
H.	○	○	○	○	○	○	○	○	○	○

9. Number of steps per task

	1= Too many	2	3	4	5	6	7	8	9= Just right	NA
I.	○	○	○	○	○	○	○	○	○	○

10. Steps to complete a task follow a logical sequence

	1= Never	2	3	4	5	6	7	8	9= Always	NA
J.	○	○	○	○	○	○	○	○	○	○

11. Feedback on the completion of sequence of steps

	1= Unclear	2	3	4	5	6	7	8	9= Clear	NA
K.	○	○	○	○	○	○	○	○	○	○

12. Please write your comments about learning here:

7. System Capabilities

Please share your experience with the speed of the system e.g: when you place an order or you are trying to place an order.Please circle the numbers which most appropriately reflect your impressions about using the ED CPOE module on a scale of 1-9. Not Applicable = NA.

1. System speed

	1= too slow	2	3	4	5	6	7	8	9	9= fast enough	NA
A.	○	○	○	○	○	○	○	○	○	○	○

2. Response time for most operations

	1= too slow	2	3	4	5	6	7	8	9= fast enough	NA
B.	○	○	○	○	○	○	○	○	○	○

3. Rate information is displayed

	1= too slow	2	3	4	5	6	7	8	9= Fast enough	NA
C.	○	○	○	○	○	○	○	○	○	○

4. Correcting your mistakes

	1= Difficult	2	3	4	5	6	7	8	9= Easy	NA
D.	○	○	○	○	○	○	○	○	○	○

5. Correcting typos

	1= Complex	2	3	4	5	6	7	8	9= Simple	NA
E.	O	O	O	O	O	O	O	O	O	O

6. Ability to undo operations

	1= Inadequate	2	3	4	5	6	7	8	9= Adequate	NA
F.	O	O	O	O	O	O	O	O	O	O

7. Ease of operation depends on your level of experience

	1= Never	2	3	4	5	6	7	8	9= Always	NA
G.	O	O	O	O	O	O	O	O	O	O

8. You can accomplish tasks knowing only a few commands

	1= Difficulty	2	3	4	5	6	7	8	9= Easily	NA
H.	O	O	O	O	O	O	O	O	O	O

9. You can use features/shortcuts

	1= Difficulty	2	3	4	5	6	7	8	9= Easily	NA
I.	O	O	O	O	O	O	O	O	O	O

10. Please write your comments about system capabilities here:

8. Technical Manuals and On-line help

Please share your experience about the help and documentation part of Cerner FirstNet ED CPOE module. How helpful was help section? e.g if you are trying to search on how to oder an MRI? etc. Please circle the numbers which most appropriately reflect your impressions about using the ED CPOE module on a scale of 1-9. Not Applicable = NA.

1. Amount of help given

	1= Inadequate	2	3	4	5	6	7	8	9= Adequate	NA
A.	○	○	○	○	○	○	○	○	○	○

2. Placement of help messages on the screen

	1= Confusing	2	3	4	5	6	7	8	9= Clear	NA
B.	○	○	○	○	○	○	○	○	○	○

3. Accessing help messages

	1= Difficult	2	3	4	5	6	7	8	9= Easy	NA
C.	○	○	○	○	○	○	○	○	○	○

4. Content of on-line help messages

	1= Confusing	2	3	4	5	6	7	8	9= Clear	NA
D.	○	○	○	○	○	○	○	○	○	○

5. Amount of help given

	1= Inadequate	2	3	4	5	6	7	8	9= Adequate	NA
E.	○	○	○	○	○	○	○	○	○	○

6. Help defines specific aspects of the system

	1= Inadequately	2	3	4	5	6	7	8	9= Adequately	NA
F.	○	○	○	○	○	○	○	○	○	○

7. Finding specific information using the on-line help

	1= Difficult	2	3	4	5	6	7	8	9= Easy	NA
G.	○	○	○	○	○	○	○	○	○	○

8. On-line help

	1= Useless	2	3	4	5	6	7	8	9= Helpful	NA
H.	○	○	○	○	○	○	○	○	○	○

9. Please write your comments about technical manuals and on-line help here:

9. Comments

This section is for you to freely share your good and bad experiences with Cerner FirstNet ED CPOE module. You can also list an suggestions on how it can be more helpful.

1. What did you like the best about working with the CPOE application in the ED?

2. What were some of the issues that you encountered while using the application?

3. What would you like to change in the system that would make it more helpful?Please mention the top three things that you would like to be changed.

APPENDIX B

MASTER LIST OF PROBLEMS IDENTIFIED, HEURISTICS ASSIGNED AND THE RATING ASSIGNED BY EACH EVALUATOR

	Task	Usability Problem	Heuristic violated	Bruce Bray	Bryan	Yuling	Neelam
1	Order Blood Products	Too much information and icons	Minimilist	2	2	2	2
		Need to refresh everytime after order, and cannot find the refresh button	Match	3	3	3	3
		Steps to be taken are listed to be remembered, they should be in a flow of screens or something similar	Memory	2	2	2	2
2	Order Medication(Ativan)	After you place the order the window stays open and no done button	closure	2	2	2	2
3	Modify an order	right click	Memory, Match	2	2	2	2
4	Cancel an order	there are two options	minimilist, language	3	3	3	3
		unclear on how to cancel	match, language	3	3	3	3
		no feedback after the order is cancelled	feedback	3	3	3	3
5	Add an allergy	too much information with red coded red status	minimilist	2	2	2	2
		force the user to choose a category which should be pre-mapped/not clear on how to find the codified symptoms	match	2	2	2	2

		creating an allergy the steps do not have a clear feedback	feedback	2	2	2	2
6	Create a plan	not sure if the plan was ordered or not	Closure	2	2	2	2
		could not sign the plan alone	control	3	3	3	3
7	Search for help	typed in "allergy" nothing shows up	Document	4	4	4	4
8	Signing orders	cannot sign individual order	flexibility	3	3	3	3
			control	3	3	3	3
9	Order a lab	nurse collecting the blood	match	2	2	2	2
		No order status/ update	match	2	3	3	3
10	Trauma order	Pop up and alerts get in the way and do not close	closure	3	3	3	3
		default values should be set	consistency	2	2	2	2
		Scroll does not work on first net at all	flexibility	2	2	2	2
11	Look up Patient History	It should be under document tab but it took 5 clicks to open pt history	Flexibility	2	2	2	2
			Match	2	2	2	2

		could not find under document tab but under power note, also it took a lot of time	Match	2	2	2	2
12	Color coding for critical values	Choice of color green	Match	2	2	2	2
13	Chronological order of orders	use same color for both high and low	Match	1	2	2	2
		click details tab data/detail	Language	1	2	2	2
14	Specific order for sinus x-ray	difficult to figure out how to change the order	match	2	2	2	2
		could not find anything if you type x-ray you have to type XR in the serach box, not doing named entry recognition	Match	2	2	2	2
15	Order IV fluids	7 clicks to place the order	Language	2	3	3	3
			flexibility	3	3	3	3
		backing up was a problem	flexibility	2	2	3	3
16	Restraining order	Protocol CS	language	3	3	3	3
		side scrolling	flexibility	3	3	3	3
		does not specify types of restraint	match	2	2	2	2
17	drug screen carbamazepine level	lot of information, not sure which level	document	3	2	2	2

18	ETOH level	could not find anything with alcohol but ETOH is fine, no spell check	Language	2	2	2	2
		takes you to the screen of nurse collect or already collected. It should be set to default.	Minimilist	2	2	2	2
19	O2 saturation	oximetry is ok but o2 sat is not	Language	2	2	2	2
		looked for SpO2, O2,oxygen but could not find anyting	Match	2	3	3	3
20	ABG	ambiguous	document	2	2	2	2
		allows duplicates	error	3	3	3	3
21	Order CT scan	search with chest CT is fine but cannot find by CT chest	language	2	2	2	2
		start and contain serach is not helpful	match	3	3	3	3
		signing requires to choose"now" and "stat"	Language	1	2	2	2
22	Order MRI	MRI brain is fine but head scan not found	language	2	2	2	2
		signing requires to choose"now" instead of "stat"	language	1	2	2	2
23	Creating a Favourite folder	no issues	Not a problem	0	0	0	0

	no problem with creating a fav folder but adding order has no feedback	feedback	2	2	2	2

APPENDIX C

QUESTIONS

1. What did you like best about the system?

   - For the routine tasks in the ED, it's very fast and easy to use. However, for ordering non-routine items, it can be confusing, offering to many similar choices for labs or scans, or not offering the one I want, particularly for MRIs

   - Very few things. See above comments regarding ease of use and number of screens/clicks required to order.
   - care sets
   - it works well for easy thing like looking up past medical records.
   - Able to enter orders at the same time of documenting H&P
   - we could build our own order sets and customize our order so we didn't have to try and navigate through a zillion different orders.
   - Nothing, it has been a thorn in my side since we started using it. I make 10x more ordering errors now than with paper charts. I understand the benefits of CPOE, but this system is so horrible it take the technical advantage out of CPOE and introduces a confounding factor - confusion.
   - relatively easy to order common studies without having to get up to find chart or call nurse.
   - improves communications re: orders between physicians and nurses/lab/X-ray
   - no written orders
   - pre done order sets
   - Ability to order my own tests. I know what did or did not get ordered

2. What are some of the issues that you encountered?

   - above
   - lab ordering is a real challenge
   - it is slow if you accidentally click the wrong button and it takes you to a page to load. it also has too many special cases (orders that you have to enter in a unique way to get them done like calling radiology or ordering some drugs from the blood bank and not the pharmacy... i thought a computer program would make this easier; I order it and the computer makes the call. we are just adding steps.)
   - double ordering by nurses and physicians, difficultly in cancelling orders
   - cerner did not interface with ARUP, so we have to do a weird work-around to get our labs done. This caused a lot of communication issues between us and the lab.
   - Can't figure out how to order labs appropriatly - nurse collect, already collected? what is that. Have to order and ABG and call the tech at teh same time- pointless. Add on labs are impossible. If they are unique you have to search on ARUP for the lab code. Sorry but do you really want your physicians to be searching the internet for lab codes? NO you want them taking care of patients.
   - Difficult to order labs/tests that are not part of the pre-definied order sets. Drug interaction system is much too invasive and routinely flags clinically insignificant interactions (ie anyone with a codeine allergy requires multiple clicks to allow any narcotics, clinically irrelevant interactions such as phenergan and IV potassium still are blocked until this is cleared, there are numerous examples but

this feature is so non-specific that it doesn't provide a safety feature, just slows work. Radiology orders are so specific that its difficult to order a test that isn't commonly ordered because there may be many variations of say an MRI with contrast of the spine and it would be better to be able to specify in special instructions rather than having to search for and find the right one, which usually involves picking the wrong one, getting called, having to cancel and reorder sometimes a couple of times. the ECU ordersets should automatically figure out the next troponin due for a chest pain patient instead of making us count 6 hours from the ED order and then typing that into the order set. The radiology orders that require a tech or radiology resident to be paged should automatically page them with the test, or print the rec, why we have to put the order in electronically and then get a pop up that we have to page them to tell them we put the order in is unclear, it defeats the efficicency of the system. The blood transfusion setup is still confusing despite the instructions. There needs to be a single order for rhogam workup and adminster 300mcg if positive. The ECU orders contiually pop up error messages about how the labs are ordered even though they are correct in the order ste and eery time we need to click on 'order anyway'.

- "time consuming

- certain steps take you back to the beginning an have to start over

- laborious to enter pt meds for the ECU"
- Duplication of orders is common
- duplicate orders
- Issues with ordering labs correctly all the time - I can easily order initial labs or pre done labs (add on order menu) but if I have to order a unique lab odds are I will do it incorrectly. Similar issue with some radiology studies

3. What are the three things that you would like to change about the system?

- "1. Able to cancel orders or change them after they are signed.

  2. The system should be able to know that the order is being placed from the ED and adjust all of the necessary parameters automatically (nurse collect, already collected, etc.) That stuff is very confusing to the user"

- Model a new screen format and order system after another one with a better system. These should be easy to find, and I am happy to get the name of the system that I worked on before. It is much better.

- online admission order. more PRECHECKED protocols/care sets. easier lab ordering. expand quick access meds. make blood easier to order. streamline ed observation unit orders

- "1. the auto import function adds way way too much information in each note so the past notes are unreadable and you have to sift through the data to get the info

you want. Past notes should have the physician note and then be linked to the ancilary info (labs and vitals and meds etc).
2. all orders entered the same way. no calling the lab or the pharmacy or technician. if I have to call, why do I have to put in the orders and then call? that is adding steps and decreasing efficiency. (its already weird that we have to type orders and then tell nurses and i still dont understand the already drawn/ nurse collected custom options that screw things up). all orders input 1 way.
3. the circles for the notes (physical exam and ROS) end up doing more harm than good. I click some but then have to type others because it doesnt say exactly what I want. In the future I will not use them but I think their presence encourages their use and they should be removed."

- Make it more clear when someone else is active in a chart and ordering a test to avoid double orders

- very difficult to search for specialty items b/c of the numerous choices for different exams and labs it was difficult to tell which one to actually order.

- Radiology entry too complicated and can't be changed by rads even after you tell them what you want. Labs are impossible to order- needs to be less specific.

- Changing the entire system would be nice.

- "1) stop using physician time (at a cost of $4 per MINUTE to the institution) to do a clerical job that could be purchased at $25/hr. but since this is unlikely...
  2) fix the problems in #2 above."

- "for individual lab orders, scree is a bit onerous and hard to find the lab you want; perhaps highlight the lab name in the middle of all the other words

- i think preset indications for rads films should be left blank so doc has to fill in the reason why getting a study"

- "1. Continuously revise care sets

  2. Improve ECU order sets and orders in general

  3. Be more specific re: how to correct errors"
  as alert the nurse when I place a new order

- "1. automaticvally order PO contrast when ordering a CT scan

  1. Simplify add-on lab process
  2. Simplify specialtly lab orders (ABG, VBG)"

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